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Long-Term Ecological Consequences In Tundra Environments of the CANOL Crude Oil Pipeline Project, N.W.T., 1942-1945

by

© Gerald Peter Kershaw

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled Long-Term Ecological Consequences In Tundra Environments of the CANOL Crude Oil Pipeline Project, N.W.T., 1942-1945 submitted by Gerald Peter Kershaw in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Abstract

The CANOL Project was a massive World War II project completed under the auspices of the U.S. Army. It directly involved much of northwestern Canada and Alaska and was larger than the Alaska Highway Project. The CANOL No. 1 Pipeline was abandoned in 1945 after 13 months of full-scale operation. No rehabilitation was attempted and most of the Northwest Territories section has remained closed to the present day.

Eight distinct types of disturbances are identified within the study area: road, false start road, bladed trail, camp yard, bulldozer track, gravel pit, gravel pit access road and oil spill. When present, each disturbance type was described from the seven physiognomically-defined plant communities in the study area: Erect Deciduous Shrub Tundra, Decumbent Shrub Tundra, Sedge Meadow Tundra, Lichen Heath Tundra, Fruticose Lichen Tundra, Cushoin Plant Tundra and Crustose Lichen Tundra.

After approximately 3.5 decades, even minor disturbances retained recognizable substrate differences when compared to control sites. Generally, the disturbance substrates were drier and more mineral-dominated with warmer subsurface temperatures. Notable organic matter accumulations were found, even on disturbances such as gravel pits. Oil spills remain oil-soaked, with significant quantities of crude oil only partly decomposed.

Plant community studies identify 15 floristically-defined plant communities within the 7 structurally-defined plant communities. Woody plants colonized disturbances within 20 years of abandonment and only roads and oil spills did not support shrubs within 9 years on average. Above-ground phytomass was lower than that of the controls on all disturbances with average values ranging from 10% to 40%. Floristic similarity between controls and disturbances varied greatly with the type of plant community. Lichens commonly showed little rocovery or recolonization. Several plant species consistently formed a high percentage of the plant cover on disturbances but were found rarely in adjacent, undisturbed areas. Floristic diversity was often greater in disturbance plant communities than in control communities. Oil spills generally had low plant cover and low species diversity, indicating that these disturbances remain hostile for most plants.

Studies of resident wildlife use indicated that most mammals prefered to use disturbed areas. In the long-term, disturbances often provide a desirable edge habitat. Many also provided elevated habitats and unimpeded travel-ways for large mammals. Mammals were generally more abundant on disturbances than in control areas.

An integration of these data indicates that Decumbent Shrub Tundra and Crustose Lichen Tundra were most and least affected respectively by the CANOL Project disturbances. Substrate moisture and temperature characteristics frequently affected the rate of organic accumulation by favouring shrub colonization.

A number of implications for future northern development are discussed. Despite a total lack of project preplanning and little concern for environmental impacts, both positive and negative, long-term ecological responses were found. A vigorous rehabilitation programme would probably have enhanced ecological recovery. All oil spills have produced negative long-term alterations and without assistance, will remain little changed in the near future.

Acknowledgements

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1. INTRODUCTION

1.1 Problem Statement

The CANOL Pipeline Project, in its abandoned state, provides an example of how a major, large scale development has altered the local environment in this northern setting. After approximately 3.5 decades, the disturbances persist in an abandoned state and there has been no attempt to rehabilitate them. The CANOL Project can therefore be used as a case study of how a number of man-induced disturbances will affect northern environments over a long time frame. Northern studies, with few exceptions, have had to work on short-term (e.g. 1 to 5 year) responses to a limited number of disturbances. However, CANOL disturbances encompass an array of examples of environmental alterations that will be common to most contemporary and future northern developments.

An holoceonotic approach has been adopted for this study. This was done in order to gain an understanding of how these long-term disturbances have affected a number of key ecosystem components. This type of study can provide an overview of ecological consequences but not necessarily the depth and detail that a specialist in a particular field would strive for. The selection and measurement of only certain key soil, vegetation and wildlife characteristics of the ecosystem was completed. The framework for this study was the major plant communities that compose the various study area ecosystems.

The rate of development in northern and alpine environments is accelerating. The exploitation of the mineral, hydrocarbon and renewable resources in previously inaccessible regions undoubtedly will disrupt established ecosystems. The effect of man-induced disturbances on these living systems is currently under study by various private and public agencies in an effort to determine the environmental costs of this exploitation. However, few other studies have been of disturbances more than 5 years of age.

The long-term success of rehabilitative measures and the use of native plant species as colonizers is often overlooked in environmental impact assessments. Most large scale projects are still in the planning stages (e.g. Norman Wells Pipeline, Alaska Highway Pipeline, Arctic Pilot Project) or have been initiated only recently in the North

(e.g. Aleyeska Pipeline, Mackenzie Delta Hydrocarbon Exploration). Consequently, extensive developments that have been abandoned for a long period of time are rare. Today, the discovery of an exploitable resource often is followed quickly by disturbances associated with exploration or development and rehabilitative measures must be planned with little knowledge of how they will evolve in the long-term. The massive CANOL Project, which affected a diversity of ecosystems, presents an ideal opportunity for the study of natural rehabilitation of man-induced disturbances over a period of three and one half decades.

Through long-term studies it may be demonstrated that, in certain instances, given sufficient time, natural processes can produce acceptable levels of recovery without intervention by man (Lawson et al. 1979). [1] In other cases, it can be shown that the current ecosystem is incapable of producing an acceptable level of recovery without some assistance. The results of this type of analysis can be used to make rehabilitation decisions in an effort to produce the best recovery rates with the least environmental and financial costs. Unnecessary rehabilitative measures can cause unforeseen impacts upon an already beleaguered ecosystem and these also must be avoided. Results of a study on the long-term ecological consequences of disturbances associated with the CANOL Project may be relevant to similar arctic and subarctic areas currently under development. The CANOL Project has produced numerous examples of the type of disturbance that recovers naturally as well as those which remain little changed after three and one half decades.

---

[1]An acceptable level of recovery will vary with the perspective of the agency or individual assessing the nature and extent of recovery. One agency may desire only erosion control on a site whereas another may require that rehabilitation result in no visual differences between the disturbance and the undisturbed, natural environment. Time frame is also an essential consideration since environmental responses in the North are slow as a result of the short, severe and variable growing season. It is not the objective of this study to provide a definition of what is acceptable, if indeed that is possible.

1.2 Overview Of The CANOL Project

The CANOL Project affected a diversity of environments over a broad geographical area. The research area encompasses the abandoned section of the CANOL Project within tundra areas in the Northwest Territories, Canada (Figure 1.1). The CANOL Project was a World War II venture commissioned by the United States (U.S.) Army but engineered, designed, constructed and operated by civilian U.S. contractors, employing a work force consisting of both American and Canadian nationals. The Project was designed to transport crude oil produced at Norman Wells on the Mackenzie River (at that time the northernmost producing oilfield on the continent) to Whitehorse in the Yukon Territory. The oil was refined in Whitehorse and the finished products transported by pipelines to Carcross and Watson Lake in the Yukon and to Fairbanks and Skagway in Alaska. These products were provided for the defense of Alaska and Canada against the Japanese and for the fueling of aircraft being flown to the U.S.S.R. over the Northwest Staging Route as part of the lend-lease agreements (Richardson 1944a).

The CANOL Project entailed the construction of a 10.2 cm diameter, 737 km crude oil pipeline from Norman Wells to the Alaska Highway at Johnson's Crossing and a 15.2 cm diameter, 192 km pipeline from that point to Whitehorse. From Whitehorse, 5.1 cm and 7.6 cm diameter pipelines distributed products to the locations mentioned above (Finnie 1945b, Hemstock 1945, U.S. Army 1950)(Figure 1.1). A total of 2,575 km of pipelines in four separate systems eventually were constructed, as well as 828 km of gravel-surfaced tote road[2], 829 km of telephone system, 2,415 km of primarily new winter roads, 10 aircraft landing strips along the Mackenzie River (U.S.Army 1950:26-37) and 58 wells of which 55 produced commercial quantities of oil (U.S.Army 1950). In addition to this, 2,736 km of water routes were upgraded (Finnie 1945b)(Figure 1.1). Construction began in October 1942 and the Whitehorse refinery commenced operations on 30 April 1944. The estimated total Project cost was $138,000,000 1942/43 U.S. dollars (Truman Committee 1944a), exceeding that of the Alaska Highway. Several Projects were carried out within CANOL and most of these involved air routes and winter roads. These are outlined in more detail in Section 2.5.3.

---

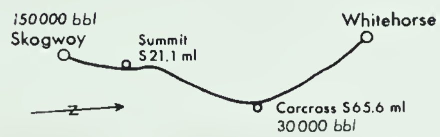
[2]Service road, not intended for light, single-axled vehicle traffic during all seasons.

Figure 1.1 Northwestern Canada and Alaska, joint defence construction projects, 1944

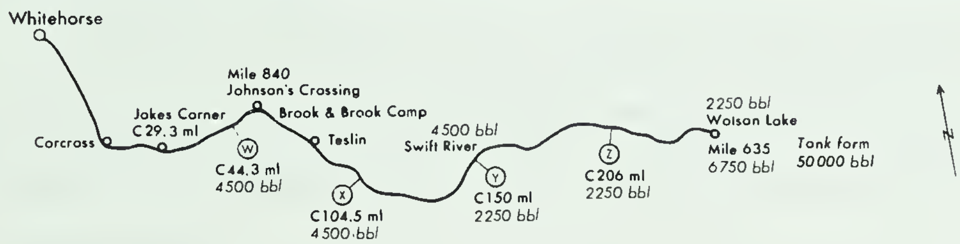
CANOL No. 1 Canol to Whitehorse - pipeline, all weather road, telephone system

○ Pump station
100 bbl Barrels of storage
S100 ml Miles from Skagway
C100 ml Miles from Carcross
W100 ml Miles from Whitehorse

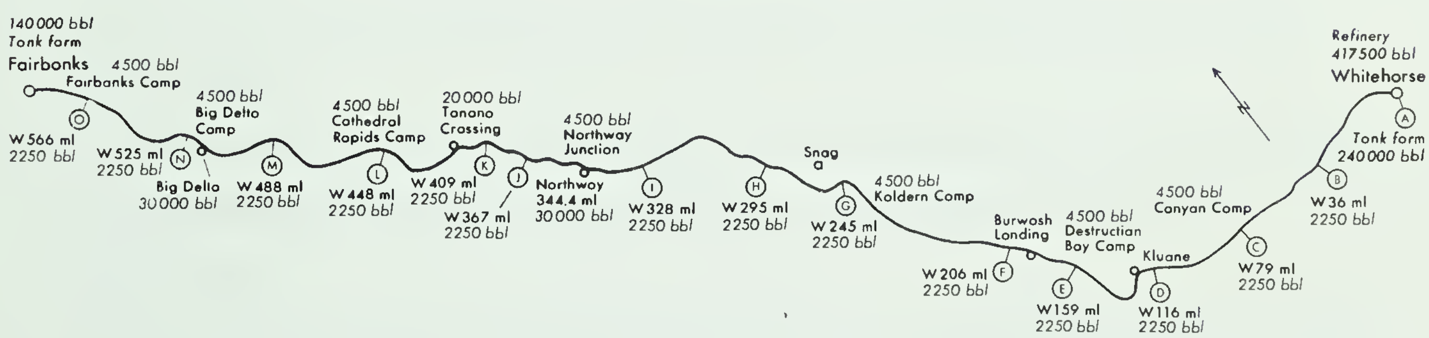
CANOL No. 2 Skagway to Whitehorse - pipeline, railroad, telephone system



CANOL No. 3 Whitehorse to Watson Lake - pipeline, highway, telephone system



CANOL No. 4 Whitehorse to Fairbanks - pipeline, highway, telephone system



CANOL No. 6 Grimshaw to Norman Wells - winter road (see main map)

After Imperial Oil Ltd. 1944

Figure 1.1 continued

Only the Northwest Territories sections of the CANOL No.1 pipeline, road and associated telephone system were considered in this study. This section of the Project, referred to as CANOL No.1 East by historical sources, was constructed between 10 October 1942 and 12 March 1944 and was abandoned by 31 May 1945. In the postwar years, oil and other developments in Alberta encouraged recovery of some of the materials along the route. In much of the area, salvage operations were completed by the fall of 1953. During the 39 years since the initial disturbances were created, the Northwest Territories section has not been artificially rehabilitated and most of the study area still remains closed to auto traffic. However, the Yukon portion of the Canol Road has been open to traffic since 1969 and the recent disturbances in this area preclude the posibility of studying long-term natural recovery there. Speculation persists that the Northwest Territories section may also be reopened eventually.

1.3 Purpose of Study

The main objective of this research was to determine how major components of the ecosystems in the study area have been affected by the man-induced disturbances initiated by the CANOL Project. With this objective as a goal, the following four purposes were outlined:

1. Describe the circumstances and nature of the disturbances at their initiation in 1942-1945.
2. Determine the current ecological characteristics of CANOL disturbances after 32-37 years.
3. Compare the disturbed areas to control or reference areas that were undisturbed in order to determine the long-term ecological consequences of the initial disturbances.
4. Discuss the implications that the results of this study will have for future northern developments.

1.4 Location

The eastern portion of the Canol Road was marked with Road Mile Posts (R.M.P.) commencing at the western bank of the Mackenzie River. Many of these still remain and all locations in this study were keyed to these permanent markers. This facilitated reference to previous accounts pertaining to the CANOL Project. Consequently, locations will be referred to by R.M.P. in the text. Where the mile post location is part of a place name it has been used directly (e.g. Camp 108).

The study area includes sections of the CANOL No. 1 East route between the Continental Divide and the Mackenzie River in the Northwest Territories (Figure 1.1). This area extends over one and a half degrees of latitude and three degrees of longitude between R.M.P. 56.5 at 64°41'N., 127°10'W. and R.M.P. 231.3 at 63°14'N., 130°02'W. The area affected by the CANOL Project generally forms a corridor which varies in width and at times includes three separate rights-of-way (i.e. road, pipeline and telephone line). An estimated total of 3.4 sq km was altered directly by the Project within the study area. This includes 117 km of road and 6.5 km of false start roads, each averaging 15 m in width; 117 km of telephone and pipeline rights-of-way, each averaging 5 m in width; and 186 gravel pits averaging 5,000 m^2 in area.

1.5 General Environmental Setting

Only areas above timberline (i.e. alpine tundra) were studied. Timberline was defined by the upper (elevational) limit of trees (Tranquillini 1979) and any member of a tree species (i.e. *Picea glauca, P. mariana* or *Abies lasiocarpa* in the study area) that possessed a single central trunk growing at least 2 m above the mean winter snow depth was considered a tree (Pruitt 1978)[3]. The height of layered branches at the base of the tree indicate the mean winter snow depth. Figure 1.2 illustrates that timberline occurs at successively lower elevations from the southwest to the northeast in the study area. Six separate sectors of tundra were studied between R.M.P. 56.5 near Canol Lake and R.M.P. 231 in Macmillan Pass (Figures 1.1 and 1.2). These extend over 117 km or 31 % of the total route east of the Continental Divide at Macmillan Pass on the Yukon/Northwest Territories border.

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[3]Nomenclature follows Porsild and Cody 1980

Topographic profiles along the Canol Road in the study areas (117 km or 73 miles), oriented from the northeast to the southwest

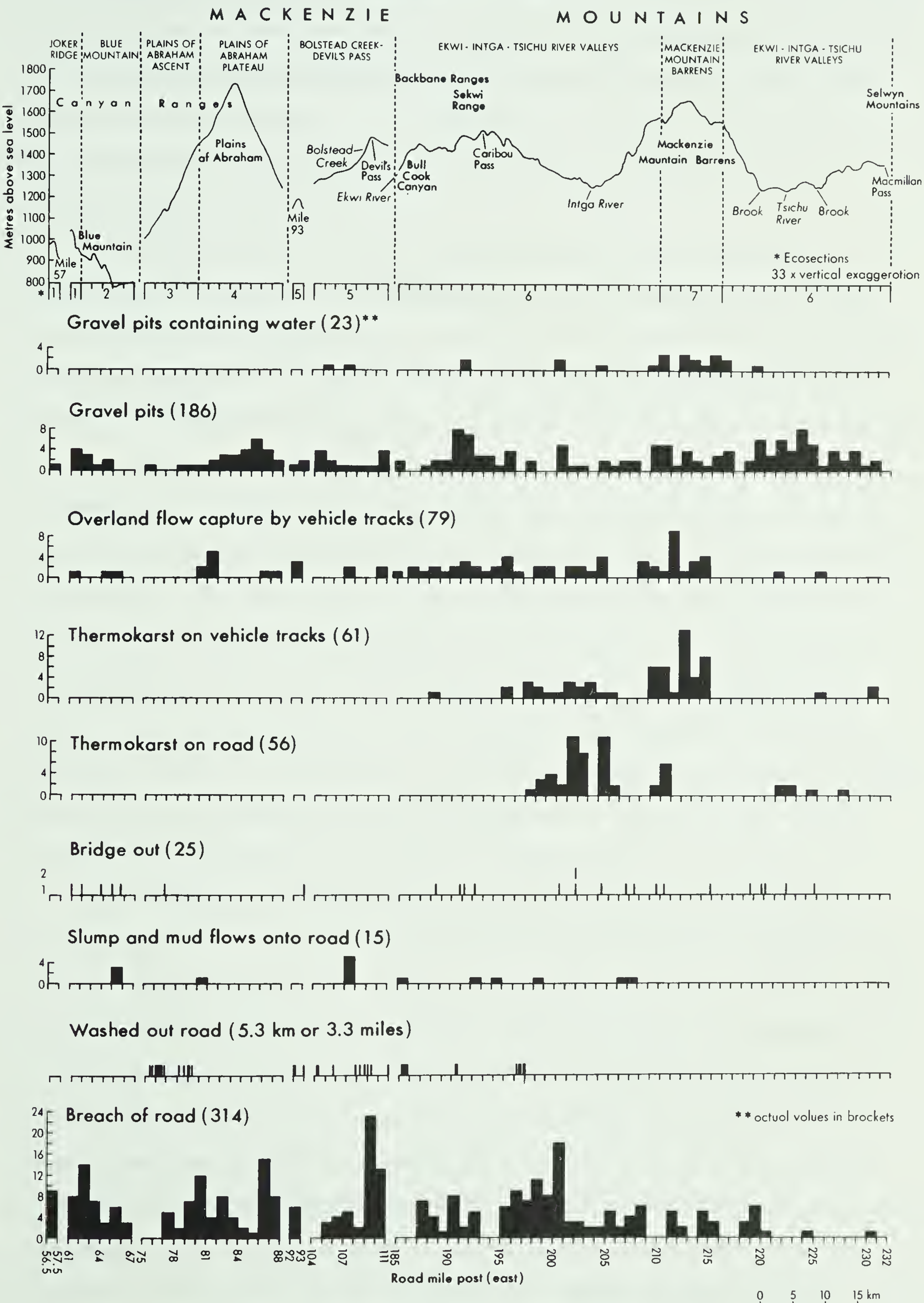

Figure 1.2 CANOL study areas with selected site alterations

Elevations of the tundra affected by the CANOL Project range from 775 m above sea level (asl) near the Mackenzie River to 1,740 m asl on the Plains of Abraham (Figure 1.2). This alpine area includes portions of the Selwyn and Mackenzie Mountain chains. Dramatic changes in elevation occur along the route. For example, on the ascent to the Plains of Abraham the pipeline gradient is 55 m/km over a distance of 13.7 km, occasionally achieving grades of 17%.

The Selwyn Mountains, located on the Continental Divide, are composed predominantly of Devonian and Mississippian shales with Cretaceous monzonite and granodiorite intrusives (Blusson 1971, 1974). Due to differential erosion, the Selwyns have higher elevations (e.g. 2,792 m at Keele Peak) than are found in the Mackenzie Mountains. The Mackenzie Mountains, which encompass the bulk of the study area, attain local heights of approximately 2,380 m north of Caribou Pass (R.M.P.93) and can be subdivided into two sections within the CANOL Project area. The western section lies west of the Twitya River at R.M.P. 130 and is composed primarily of Proterozoic and Cambrian limestones, shales, siltstones and sandstones (Blusson, 1971, 1974). The eastern section extends from the Twitya River to the Carcajou River at R.M.P. 28 and is composed primarily of Proterozoic dolomites; Cambrian siltstones, sandstones and shales; Ordovician quartzites, dolomites and slates; Silurian dolomites; and Devonian dolomites. Three of the five ranges of the Mackenzie Mountains are included in the study area (i.e. the Sekwi, Backbone and Canyon Ranges) plus two large plateaus named the Mackenzie Mountain Barrens and the Plains of Abraham (Figures 1.1 and 1.2).

Field evidence, in conjunction with a few published sources, indicates that extensive sections of this area were unglaciated during the Wisconsin glaciation (Bird 1974a, 1974b; Hanley et al. 1973; Hughes 1970a, 1970b; Prest et al. 1967; Prest 1969). Those sections along the road between R.M.P. 158 and R.M.P. 231 were glaciated whereas unglaciated areas are found between R.M.P. 30 and R.M.P. 158. This does not mean that alpine glaciers were absent from these regions but rather that they were generally small and localized, not extending onto the valley bottoms. The numerous plateaus and intervening valleys between R.M.P. 23 and R.M.P. 158 commonly exhibit such features as tors, cryoplanation terraces, stone pitting, blockfields and blockslopes, continuous patterned ground, interfingering spurs, V-shaped valley profiles and

coalescing piedmont accumulations. These features suggest considerable antiquity and hence the exposure of these surfaces during the Wisconsin glaciation.

Climatic data for the Mackenzie and Selwyn Mountains are available from three reporting stations (Figure 1.1)

1. Tungsten, Northwest Territories (since 1966)
2. Sheldon Lake, Yukon Territory (May to September since 1970)
3. Tsichu River, Northwest Territories (since 1974).

Unfortunately these have not provided continuous records and were only established recently. Data from the Norman Wells station (established in 1943) include the following: mean annual temperature of −6.3°C, mean annual precipitation of 335 mm, mean annual snowfall of 143.3 cm over 10 months, 126 frost free days, and two months with an average of one day with freezing temperatures and one month with none (Burns 1973). These data best typify the eastern portion of the study area (Figure 1.1).

The Tsichu River station (established in 1974) is located inside the western border of the study area (Figure 1.1) and consequently these data are most relevant to this study. The Tsichu River station has a mean annual temperature of −7.5°C; mean annual precipitation of 470 mm and a mean annual snowfall of 278 cm. The mean July temperature is 10° C. However, frosts occur in every month of the year with maximum precipitation occurring in the July to October period (Figure 1.3) Mean daily temperatures are above freezing from late May to mid-September.

The entire study area falls within a Continental climatic regime. However, this is considerably modified by the alpine setting. As a result, the eastern portion, which lies within the Mackenzie Mountain rainshadow, receives considerably less precipitation than does the western portion.

Porsild conducted botanical research along the Canol Road in 1944. He described six major vegetation types (Porsild 1944a, 1944b,, 1945, 1951) but only four of these were found in the Northwest Territories section (Porsild 1951). These were:

1. white spruce (*Picea glauca*)-balsam poplar *Populus balsamifera*
2. white spruce-paper birch (*Betula papyrifera*)-black spruce (*Picea mariana*)
3. black spruce
4. alpine tundra

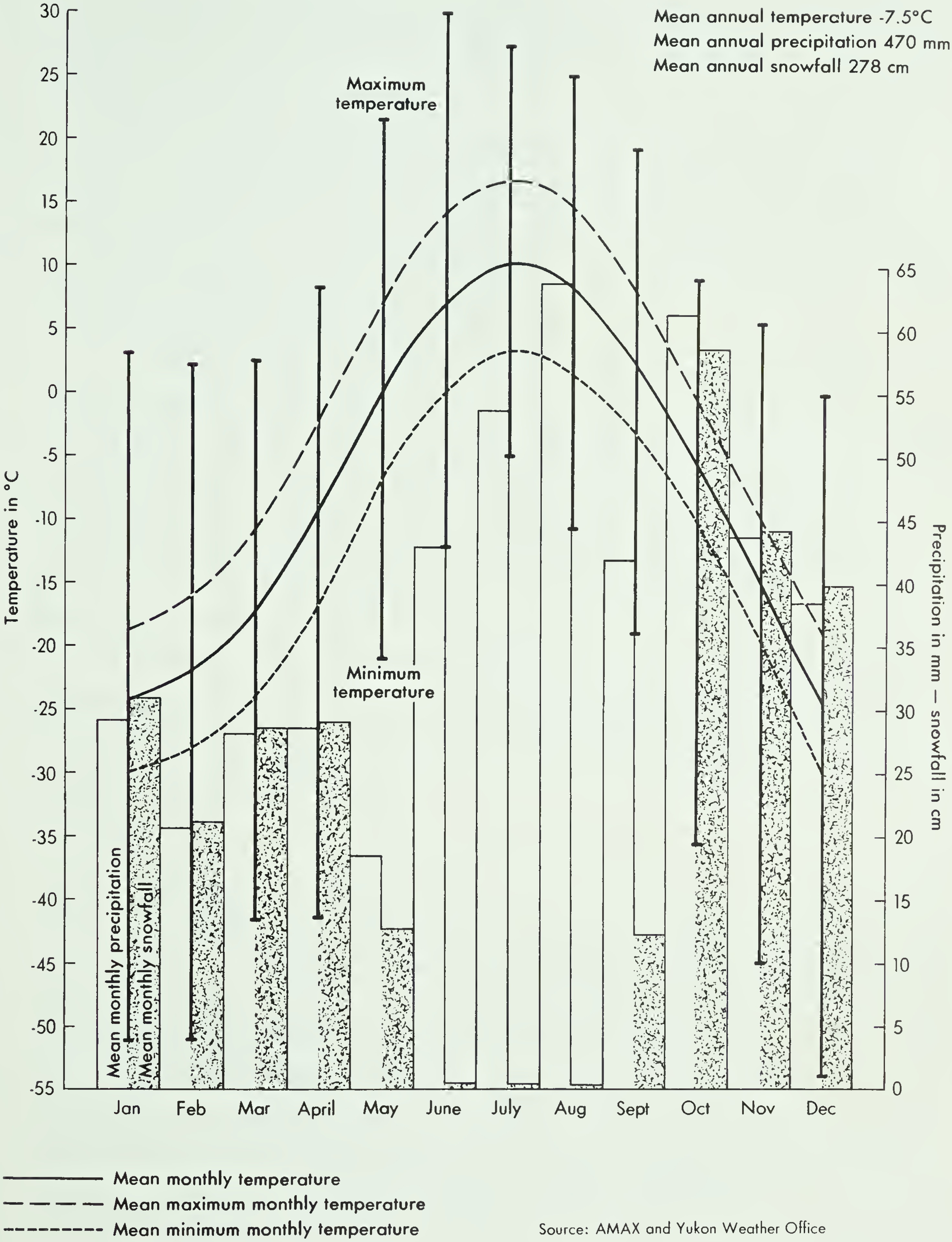

Figure 1.3 Temperature and precipitation characteristics: Tsichu River meteorological station, N.W.T., Canada, October 1974 to October 1981

The tundra plant communities vary considerably in their characteristics with dominant plants including dwarf shrubs, forbs, sedges, grasses, lichens, mosses, or combinations of these plant types.

Rand conducted zoological research along the Canol Road in 1944. He made notes on wildlife sightings, and where possible, collected specimens (Rand 1945a, 1945b, 1946). More recent work has been completed by the Canadian Wildlife Service (see Simmons entries in Selected References) and by the Northwest Territories, Fish and Wildlife Service (Sam Miller personal communication).

Wildlife of the alpine tundra includes large mammals such as the woodland caribou (*Rangifer tarandus caribou*), moose (*Alces alces*), grizzly bear (*Ursus arctos*), wolverine (*Gulo gulo*), wolf (*Canis lupus*), and Dall's sheep (*Ovis nivicola dalli*)[4]. Smaller mammals include the arctic ground squirrel (*Spermophylis parryii*), pika (*Ochotona princeps*), hoary marmot (*Marmota caligata caligata*), red-backed vole (*Clethrionomys rutilus*) and Siberian lemming (*Lemmus sibiricus*). The avifauna is rich with Willow Ptarmigan (*Lagopus lagopus*) and Rock Ptarmigan (*L. mutus*), Gyrfalcon (*Falco rusticolus*), Golden Eagle (*Aquila chrysaetos*), Long-tailed Jaeger (*Stercorarius longicaudus*), Raven (*Corvus corax*), Short-eared Owl (*Asio flammeus*), American Golden Plover (*Pluvialis dominica*), Old Squaw (*Clangula hyemalis*), Northern Shrike (*Lanius excubitor*), numerous sparrows and many other birds[5].

1.6 Ecosections Within the Study Area

Portions of the study area possess combinations of environmental characteristics that place them in broad, natural regions. These 'ecosections' (Wiken 1979) have relatively homogeneous bedrock geology, geomorphic history, topographic position, mesoclimate, soils, vegetation physiognomy, floristics and wildlife. Ecosections generally have few characteristics in common. However, some plant communities can be found in two or more of the ecosections in the study area. The plant communities referred to in the following descriptions will be presented in more detail in Section 4.3.1.

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[4]Nomenclature follows Banfield 1977 and Youngmann 1973
[5]Nomenclature follows Godfrey 1966

The six regions of tundra comprising the study area are discernible in Figure 1.2 where the seperate topographic profile of each is included. Within these areas, the following ecosections have been defined on the basis of the characteristics noted above:

1. Joker Ridge
2. Blue Mountain
3. Plains of Abraham Ascent
4. Plains of Abraham Plateau
5. Bolstead Creek – Devil's Pass
6. Ekwi–Intga–Tsichu River Valleys
7. Mackenzie Mountain Barrens

1.6.1 Joker Ridge Ecosection

This ecosection is found in the northeastern corner of the study area between R.M.P. 56.5 and R.M.P. 62.5, within the ice-free zone of the Wisconsin glaciation (Figure 1.2). It includes disturbances at elevations ranging from 817 m to 990 m (Plate 1.1) The dolomite bedrock (Aitken and Cook 1974) is thinly mantled by felsenmere and poorly developed soils. On the mountain slopes, frost-riven bedrock up to 2 m thick has created extensive blockfields and blockslopes. Massive patterned ground can be found but few of these features show evidence of recent cryoturbation. This ecosection includes ridge crest, mountain side and valley bottom sites.

Mesoclimatic information is non-existent for this region but some characteristics can be inferred from the environmental setting. The zone lies within the first mountain range of the Eastern Mackenzie Mountains, within the rain shadow of the greater Mackenzie Mountain belt to the west and abutting the Mackenzie Plains on the east. Consequently, total precipitation is much less than that received by the western portion of the study area. Its position along the border of the Mackenzie Plains results in a greater influence from air masses advected from the east, which are presumably the source of the bulk of its precipitation.

Soils are Regosolic and thin to discontinuous, usually with a shallow lithic contact. Surface layers can be organic and total vertical development does not exceed 30 to 35 cm.

1.1 Joker Ridge Ecosection: unglaciated terrain with Decumbent Shrub Tundra dominant above the Erect Deciduous Shrub Tundra of the valleys

1.2 Blue Mountain Ecosection: blockslopes merge with Lichen Heath and Decumbent Shrub Tundra

Plant communities in this ecosection include primarily shrubby vegetation such as Erect and Decumbent Shrub Tundra. Lichen Heath and Crustose Lichen Tundra are also present but occur less commonly (Table 1.1). The communities dominated by taller shrubs are utilized by moose and caribou. Wolves and foxes are also found throughout the area for most of the year. Arctic ground squirrels are present wherever burrow construction is possible and pikas inhabit the blockfield areas.

There is no evidence of ice-rich permafrost in this dry, rocky area. However, fluvial activity has washed out the road and removed bridges in several major seasonal drainage ways (Figure 1.2) while other stretches have experienced little morphological change. Shrubs have colonized road shoulders and ditches, bladed trails, bulldozer tracks and gravel pit access roads. Gravel pits appear to have changed little and still retain steep walls. Many also have ponded water in at least a portion of the depression (Figure 1.2). Bladed trails and bulldozer tracks do not channel runoff in this ecosection because precipitation is light and the substrate freely-drained.

CANOL road and pipeline construction activities in this area occurred during the fall of 1943, followed by winter construction of the telephone line. Separate corridors can be found for each right-of-way. However, the road and associated facilities created the most obvious disturbance within the tundra areas. Road, gravel pit, bladed trail and bulldozer track sites have been studied in this ecosection.

1.6.2 Blue Mountain Ecosection

This ecosection encompasses the area between R.M.P. 62.5 and R.M.P. 67 on the Canol Road and also includes an alternate winter route with mile posts labelled as R.M.P. 61 to R.M.P. 63 (Figure 1.2). Disturbed areas within this zone lie at elevations ranging from 914 m to 1,042 m on northeast-facing slopes and in two mountain saddles through which the Project passed. The road extends around the side of Blue Mountain, dropping down into each of the four drainage ways encountered (Plate 1.2).

Bedrock in this ecosection is mainly quartzite (Aitken and Cook 1974) and blockfields contain lichen-covered blocks up to 2 m in diameter. The area shows little evidence of late Wisconsin glaciation, with the exception of some poorly developed cirques at high elevations. Periglacial features are much in evidence, with slopes mantled

Table 1.1: Plant communities within CANOL Project study area ecosections, N.W.T.

	Ecosections						
Plant Communities	Joker Ridge	Blue Mountain	Plains of Abraham Ascent	Plains of Abraham Plateau	Bolstead Creek - Devil's Pass	Ekwi-Intga-Tsichu Rivers	Mackenzie Mountain Barrens
Erect Deciduous Shrub Tundra	A				A	D	
Decumbent Shrub Tundra	D	F	D	R	F	F	F
Sedge Meadow Tundra				R	R	O	D
Lichen Heath Tundra	R	A			A	F	R
Frutícose Lichen Tundra		R			R	O	
Cushion Plant Tundra				D			
Crustose Lichen Tundra	A	A	F	D	O	R	

'D':Dominant(45-100%); 'A':Abundant(30-45%); 'F':Frequent(10-30%); 'O':Occasional(5-10%); 'R'':Rare(0-5%)

by active gelifluction lobes, extensive blockfields and blockslopes, nivation zones and small to large scale, active and inactive patterned ground. The results of over–snow transport are evident and snow avalanches occur frequently during the winter and early spring. Fluvial transport is restricted to drainage ways and debris flows are common.

This ecosection lies within the Mackenzie Mountain rainshadow and receives the bulk of its precipitation from the east. Winter snow is insufficient to cover the larger blocks in the blockfields and is redistributed by winds.

When present, upland soil is Regosolic with evidence of weathering generally less than 10 to 15 cm in depth. Surficial organic deposits up to 20 cm in thickness are occasionally found. On flatter terrain in the valleys, Organic and Brunisolic soils are present.

Plant communities in this ecosection include Decumbent Shrub Tundra, Sedge Meadow Tundra, Lichen Heath Tundra, Fruticose Lichen Tundra and Crustose Lichen Tundra (Table 1.1). Dall's sheep and pikas utilize the mountain slopes while woodland caribou frequent the valley bottoms. Arctic ground squirrels are found throughout the area and wolves and foxes utilize all but the steeper slopes.

Since this area is very active geomorphologically, with frequent avalanches, slumps, mudflows and rockfalls, a number of alterations to initial disturbances have occurred. Where the road traverses slopes, runoff has been forced along the ditch and often has overflowed the roadbed. The effects of erosion have been considerable, and in all draws, bridges and culverts no longer exist and the road has been washed away (Figure 1.2).

Canol Road construction in this area commenced in late July 1943. In the winter of 1944–1945, the alternate route between R.M.P.61 and R.M.P.69 was constructed and used. The pipeline was located up to 4 km from the original road route and the telephone line lay between the two. Pipeline construction was carried out from late October 1943 to late January 1944 and the telephone line construction period extended from early December 1943 to mid–January 1944. Little alteration of the terrain was observed in those areas affected by pipeline or telephone line construction. Road, false start road, bladed trail, bulldozer track, gravel pit, and gravel pit access road sites were studied in this ecosection.

1.6.3 Plains of Abraham Ascent Ecosection

The area between R.M.P. 75.5 and R.M.P. 80 lies within this ecosection (Figure 1.2). Elevation ranges from 1,341 m to 1,457 m in this north-south trending valley which climbs to the Plains of Abraham Plateau (Plate 1.3)

This ecosection lies within the area that was ice-free during the Wisconsin glaciation and is underlain by dolomite bedrock (Aitken and Cook 1974) which outcrops occasionally in the main stream channel. Geomorphologically, this ecosection has been dominated by fluvial erosion and deposition, with a seasonally active channel redistributing alluvium annually. Tributaries have built relatively stable alluvial fans where they enter the main valley but few surfaces have a continuous vegetation cover. Blockslopes mantle the valley walls and extend onto the valley bottom.

The area is dry, soils are excessively drained, there is no surface water storage and the streams are intermittent. However, winter snow cover is generally deep as a result of the deposition of drifting snow from the high plateau.

Soils are poorly developed with only pockets of silty alluvium showing vertical zonation. Organic surface layers are thin to discontinuous and less than 5 cm thick when present. Substrates are generally composed of coarse alluvium which is frequently redistributed.

Plant communities in this ecosection include Erect and Decumbent Shrub Tundra with Crustose Lichen Tundra on the blockslopes (Table 1.1). Dall's sheep and woodland caribou are found throughout the area. Pikas reside in the blockslopes and ground squirrels are common where more stable surfaces are found.

Most disturbances have been affected by fluvial processes on a continuing basis as the stream channel frequently changes course, removing anything in its path. Only isolated stretches of the rights-of-way remain intact after 35 years (Figure 1.2).

Construction was carried out during September 1943, November 1943 to February 1944, and January 1944 for the road, pipeline and telephone lines respectively. The road required substantial maintenance until the time of abandonment. Road, bladed trail and gravel pit disturbances were studied in this ecosection with roads and gravel pits the most common.

1.3 Plains of Abraham Ascent Ecosection: block slopes extend to the valley bottom. On this day, heavy thunder showers produced a temporary channel along the upslope side of the road

1.4 Plains of Abraham Plateau Ecosection: extensive patterned ground has developed on these flat surfaces

1.6.4 Plains of Abraham Plateau Ecosection

The area between R.M.P. 80 and R.M.P. 88 lies on the Plains of Abraham, a flat-topped, unglaciated plateau with elevations ranging from 1,457 m to 1,710 m (Figure 1.2)(Plate 1.4). This zone has been extended to include the R.M.P. 92 - R.M.P. 93 area at 1,219 m.

Dolomite bedrock (Aitken and Cook 1974) underlies from 0.5 m to 2 m. of frost riven bedrock and active patterned ground, blockfields, cryoplanation terraces and tors are common.

During the summer, the area is dry as a result of low precipitation and low moisture retention capacity. Winter snow cover is thin to discontinuous on the exposed plateau due to the combined effect of wind erosion and low snowfall.

The Regosolic soils are limited in extent and are poorly developed, with little organic accumulation. Organic surface layers are best developed on the snowflush and seepage sites. Most of the area is covered by limestone and dolomite blocks. Chemical weathering has heavily pitted rock surfaces, by the removal of calcium carbonate in solution.

Plant communties in this ecosection include Decumbent Shrub Tundra, Sedge Meadow Tundra, Cushion Plant Tundra and Crustose Lichen Tundra (Table 1.1). Dall's sheep, arctic ground squirrels and pikas are common and caribou are frequently observed during the post-calving period in large groups or as solitary animals. With the exception of Rock Ptarmigan, no animals were observed in this area during the winter.

1.6.5 Bolstead Creek - Devils Pass Ecosection

Bolstead Creek and Devil's Pass are located between R.M.P. 104.5 and R.M.P. 111.5 at elevations of from 1,247 m to 1,506 m (Plate 1.5 and Figure 1.2). The valley of Bolstead Creek trends north-south whereas Devil's Pass is oriented east-west (Figure 1.1).

Bedrock in this ecosection is predominantly dolomite from R.M.P. 104.5 to R.M.P. 109.5, with quartzite in the Devil's Pass area. This ecosection lies within the late Wisconsin ice-free area but there is some morphological evidence of high elevation cirques. Aufeis is common on Bolstead Creek and large-scale patterned ground is found

1.5 Bolstead Creek - Devil's Pass Ecosection: Lichen Heath and Erect Deciduous Shrub Tundra dominate in Devil's Pass

1.6 Ekwi-Intga-Tsichu River Valleys Ecosection: Erect Deciduous Shrub Tundra dominates the broad valley floor in the Intga River Valley

nearby. Blockslopes extend to low elevations on north- to east-facing slopes and stone garlands and lobate rock glaciers can be found within 1 km of the CANOL Project rights-of-way. Active and inactive small scale patterned ground is common and palsas are found in Devil's Pass.

Snow and slush avalanches are common in late winter and spring and debris flows often extend onto the valley bottom. This zone receives greater precipitation than do the ecosections farther to the east. During the winter, snow can be 40 cm to 75 cm deep with extensive, wind-packed drifts. Winds can be very strong, due to the funnelling effect of these deeply incised valleys. The high mountains on the southern side of the valleys block direct sunlight during the winter, and in the summer Bolstead Creek valley receives direct sunlight for only a few hours each day.

Soils in this ecosection range from organic-rich to Regosolic. The Organosols have developed in wetlands and Brunisols and Regosols are found on better-drained sites. Brunisols are best developed on silty alluvium while Regosols are commonly on coarse alluvium and colluvium.

Plant communities in this ecosection include Erect Deciduous Shrub Tundra, Decumbent Shrub Tundra, Sedge Meadow Tundra, Lichen Heath Tundra and Fruticose Lichen Tundra (Table 1.1). Dall's sheep,woodland caribou, grizzly bears, porcupines, wolverines, arctic ground squirrels and pikas utilize this area, although caribou do not overwinter here.

Linear disturbances that crossed drainage ways were obliterated and those crossing slopes often redirected and concentrated surface wash (Figure 1.2). Ditches were incised and the roadbed was frequently eroded or breached. Disturbances on blockslopes remain little altered since abandonment. In particular, the road, false start road, bladed trail and gravel pit sites appear fresh and unchanged after 35 years.

The CANOL Project construction period in this ecosection was late September 1943 to late June 1944, mid-October 1943 to late February 1944 and February 1944 for the road, pipeline and telephone lines respectively. The telephone line corridor was separated from the road and pipeline rights-of-way by up to 0.5 km and a false start road was constructed on the north side of Devil's Pass, opposite the Canol Road. Road, false start road, bladed trail, camp yard, bulldozer track, gravel pit, gravel pit access road

and oil spill disturbances were studied in this ecosection.

1.6.6 Ekwi - Intga - Tsichu River Valleys Ecosection

This is the largest ecosection in the study area and encompasses disturbances between R.M.P. 185.5 and R.M.P. 210.8 and between R.M.P. 216.5 and R.M.P. 231 at elevations ranging from 1,256 m to 1,593 m (Plate 1.6). The area extends from Bull Cook Canyon on the Ekwi River, through Caribou Pass, down the valley of the Intga River and up one of its tributaries to the border of the Mackenzie Mountain Barrens. On the southeastern side of the Mackenzie Mountain Barrens, it continues to the Yukon border, the western limit of the study area (Figures 1.1 and 1.2).

The bedrock is complex, consisting of shales, siltstones, sandstones, dolomites, limestones, orthoquartzite and quartzite west of the Mackenzie Mountain Barrens and slate, siltstone, shale, argillite, quartz monzonite and granodiorite towards the Continental Divide (Blusson 1971).

This region was glaciated during the Wisconsin period and several of the peaks in the area retain glacierettes. Periglacial features are common and include palsas, peat plateaus, open system pingos, active and inactive patterned ground, gelifluction lobes and rock glaciers. Ice-rich permafrost exists in palsas and peat plateaus and many till bodies in the area may also have permafrost. Debris flows, snow and slush avalanches and rockfalls have built up extensive debris slope deposits. Recent alluvium is gravelly and confined to the modern stream bottoms where braided reaches are common. Aufeis may occur in braided reaches of the Tsichu River but is not present every year.

Soils include Organics, Brunisols and Regosols. When permafrost is present, Cryosols result. This commonly occurs with organic-dominated soils. Extensive, organic-dominated fens occur in the vicinity of Caribou Pass. Peaty layers have accumulated on most surfaces but vary in thickness from 5 cm to 2 m. On Brunisols they average from 15 to 20 cm in thichness. Areas of clay-rich soils can be found in glacial till or in former lake bottoms.

The main plant community in this ecosection is Erect Deciduous Shrub Tundra. However, Decumbent Shrub Tundra, Sedge Meadow Tundra, Lichen Heath Tundra, Fruticose Lichen Tundra and Crustose Lichen Tundra are also present (Table 1.1). Moose,

woodland caribou, grizzly bears, wolves, foxes, wolverines, ermine, marmots, pikas, porcupines and arctic ground squirrels are found throughout this area. Dall's sheep are also seen but were not noted along the Project rights-of-way. Many of these species show definite habitat preferences within this ecosection. For example, moose spend much of their summer in wetland areas and during the winter, browse on shrubs throughout the area. Caribou migrate out of the area in the late fall and return in early spring.

This ecosection contains a large number of palsas and peat plateaus. Several palsa fields and ice-rich till bodies were traversed by the road, false start roads, bladed trails and/or bulldozer tracks, resulting in ground-ice melt and the creation of a number of thermokarst ponds (Figure 1.2). Where the road was confined to the bed of Bull Cook Canyon, it has been eroded and almost entirely removed (Figure 1.2). Along the Intga River, bladed trail and bulldozer tracks now channel surface drainage for significant distances (Figure 1.2). Bridges on smaller creeks have been left standing with the road approaches eroded away while larger bridges have been undercut and have sustained irrepairable structural damage.

In the eastern section of this ecosection Canol Road construction began in early December 1943 and was incomplete when the Project was abandoned. However, by early January 1944 the winter and dry weather tote road was useable. The pipeline and telephone line construction periods extended from February to early March 1944 and from January to February 1944 respectively. Construction of an alternate road between R.M.P.198 and R.M.P.200 was initiated but was never completed. Road, false start road, bladed trail, camp yard, bulldozer track, gravel pit, gravel pit access road and oil spill disturbances were studied in this ecosection.

In the western section of this ecosection Canol Road construction began in late December 1943 and maintenance activities continued until the time of abandonment in 1945. The pipeline and telephone line construction periods extended from early February to mid-March 1944 and from January to February 1944 respectively. The rights-of-way deviated by as much as 1.5 km but were generally within 100 m of one another. All types of CANOL disturbances were studied in this ecosection.

1.6.7 Mackenzie Mountain Barrens Ecosection

This ecosection encompasses disturbances between R.M.P. 210.8 and R.M.P. 216.2 on the Mackenzie Mountain Barrens, an undulating plateau with elevations ranging from 1,710 m to 1,567 m (Figures 1.1 and 1.2, Plate 1.7).

Bedrock is primarily slate and shale (Blusson 1971) with a thin, discontinuous covering of till. The Mackenzie Mountain Barrens was glaciated during the Wisconsin glaciation and periglacial features are ubiquitous and active, suggesting that permafrost underlies much of the terrain. Features include palsa/peat plateau complexes and many types of patterned ground.

This area is at least 300 m higher than the Tsichu River Meteorological Station and has a cooler, wetter climate. The snowpack averages from 45 to 65 cm with little redistribution by wind.

Soils include Organic Cryosols and Brunisolic Cryosols. Two-metre peat accumulations have been noted in exposures on palsas. Regosols also occur in areas where bedrock is close to the surface.

The predominant plant community in this ecosection is Sedge Meadow Tundra (Table 1.1). Moose, woodland caribou, grizzly bears, wolverines, ermine, wolves, foxes and arctic ground squirrels utilize this area. Caribou migrate onto the Mackenzie Mountain Barrens in large numbers during both the post-calving period and the rut. Wolverines, ermine and lemming were the only winter inhabitants noted.

Extensive areas of patterned ground cover much of this ecosection. Road disturbances have produced numerous examples of thermokarst, often creating ponds on or adjacent to the roadbed (Figure 1.2). Bladed trails and bulldozer tracks have had remarkably little effect when crossing palsas and peat plateaus. Depressions are visible but few examples of complete thaw or water impoundment were found. Bulldozer disturbances frequently channelize surface flow and the road berm often dams surface runoff with subsequent breaches and/or extensive erosion. Bridges and culverts accoss existing drainage ways are seldom serviceable (Figure 1.2). From the air, bulldozer tracks are particularly evident, though these features are often difficult to locate when on the ground. A number of wetlands have been created in association with gravel pits (Figure 1.2).

1.7 Mackenzie Mountain Barrens Ecosection: palsas and peat plateaus cover extensive areas on this Sedge Meadow Tundra-dominated plateau

1.8 Erect Deciduous Shrub Tundra: dominated by *Betula glandulosa*, is extensive in the Tsichu River valley. The Mackenzie Mountain Barrens Ecosection is visible on the skyline.

The CANOL construction period in this ecosection extended from November 1943 to October 1944. Two main rights-of-way up to 2 km apart were used. Disturbances studied include road, bladed trail, camp yard, bulldozer track, gravel pit and gravel pit access road sites.

1.6.8 Ecosections Summary

Indications are that the geomorphological consequences of actions initiated 34-36 years ago have, as yet, not reached a stable state in many cases. In a number of ecosections there are sites where new drainage ways are still developing along disturbances, where slumping continues to bring slopes into more stable angles and where thermokarst appears to be enlarging thaw ponds in disturbances. These processes are actively modifying CANOL disturbances just as they continue to operate in adjacent, undisturbed areas. In some cases, the long-term consequences of the initial disturbances would have been difficult to determine. However, there are also numerous examples where stability has been reestablished. Nevertheless, it is significant that geomorphological instabilities still exist in response to the initial disturbances and, without detailed, site specific studies it is evident that little can be stated about their future development.

1.7 Plant Communities

The following plant communities were identified within the study area based upon stand physiognomy.

1. Erect Deciduous Shrub Tundra (Plate 1.8) was dominated by tall (greater than 30 cm high) shrubs. These were commonly *Betula glandulosa* and *Salix* species with a diverse understory composed of fruticose lichens or herbaceous vascular plants.
2. Decumbent Shrub Tundra (Plate 1.9) was dominated by prostrate (less than 30 cm high) shrubs. The dominant species varied from site to site but were always woody plants.
3. Sedge Meadow Tundra (Plate 1.10) was dominated by herbaceous plants, although prostrate woody plants often occurred beneath them. *Carex* species were most abundant on these poorly drained sites.

4. Lichen Heath Tundra (Plate 1.11) was dominated by lichens, although heath plants were also common. *Cassiope tetragona* was usually the most common vascular plant while *Cladonia* species were the most abundant non–vascular plants.
5. Fruticose Lichen Tundra (Plate 1.12) was not common in the study area. *Cladonia* species, *Alectoria ochroleuca* and *Cetraria* species were most abundant.
6. Cushion Plant Tundra (Plate 1.13) was dominated by cushion forming plants such as *Dryas* species, *Silene acaulis, Salix dodgeana* and other species that take on this growth form under stress. There were also a number of lichens such as *Cetraria* species and *Cladonia* species.
7. Crustose Lichen Tundra (Plate 1.14) was not common in the study area. This epilithic plant community was dominated by species that can be divided into two groups those on acidic and those on basic substrates. Genera such as *Rhizocarpon, Polyblastia, Lecidea* and *Umbilicaria* were dominant.

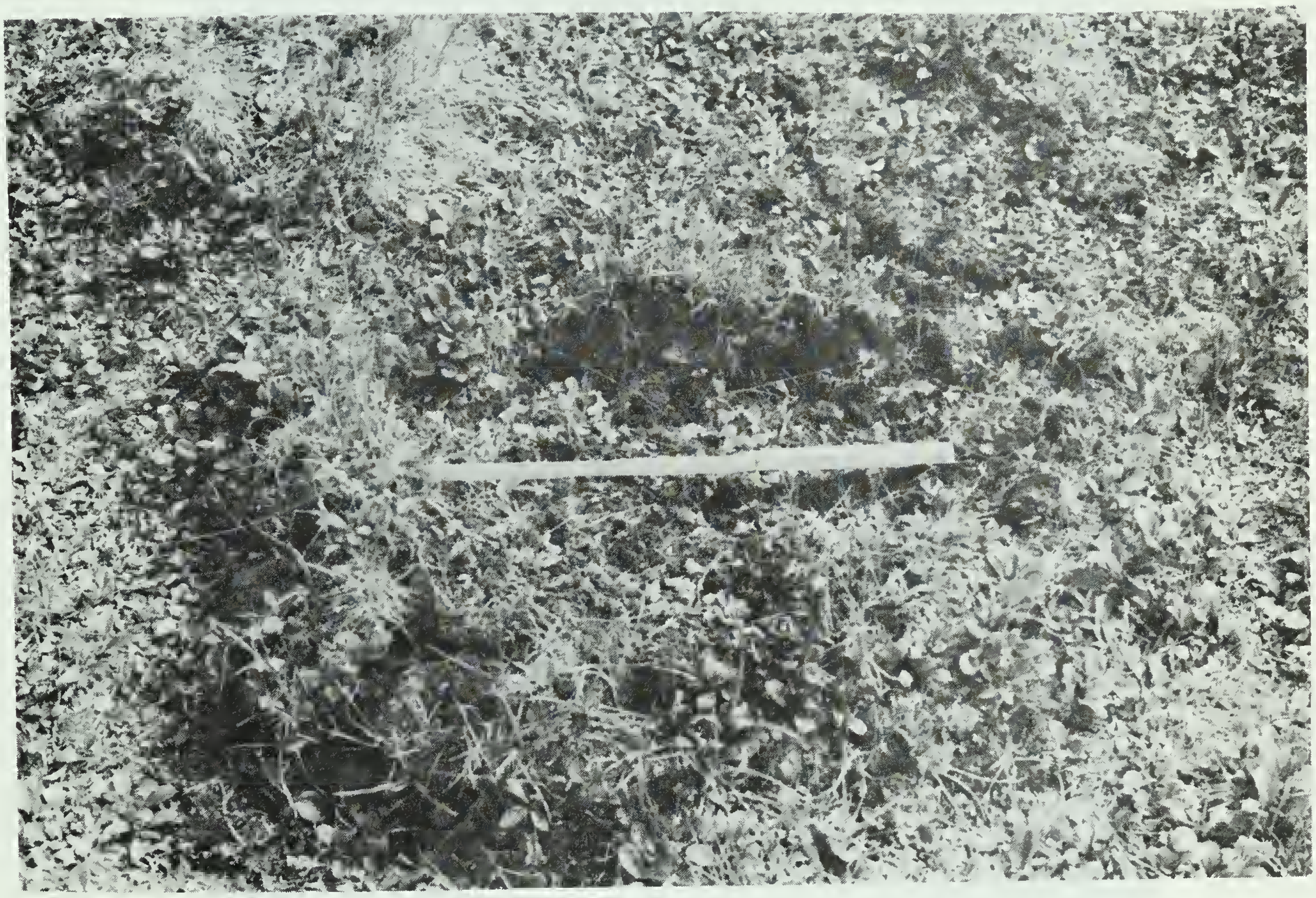
The definition of these communities was based solely on structure and therefore they can include several floristically defined plant communities. More detailed descriptions are provided in Section 4.3.1.

1.8 Types Of Disturbances

Within the study area, the following eight distinct types of disturbances were recognized:

1. road
2. false start road
3. bladed trail
4. camp yard
5. bulldozer track
6. gravel pit
7. gravel pit access road
8. oil spill

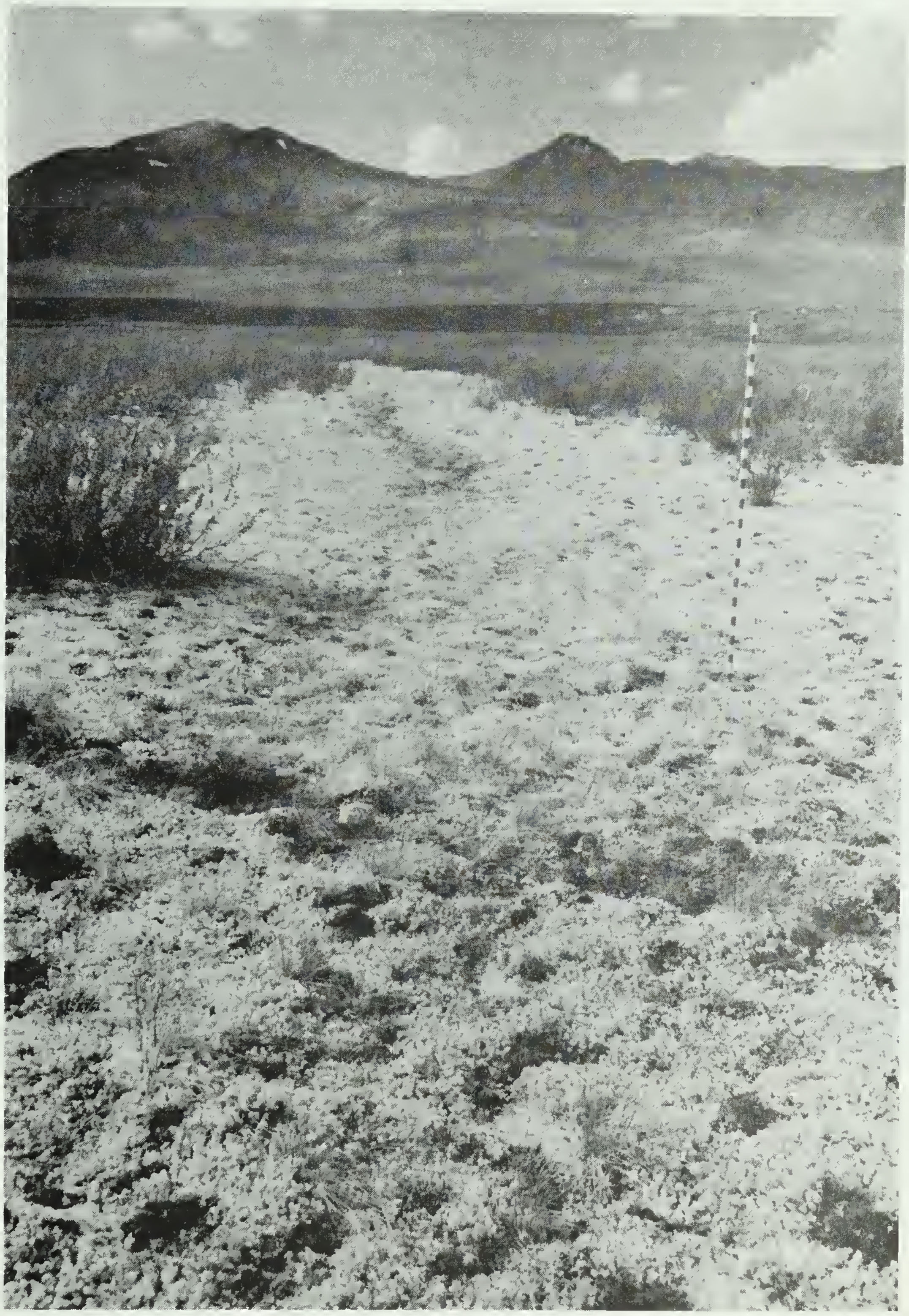
The road type is self–explanatory although variations in attitude did occur (Plate 1.15). The road surface was above, below or at the same level as the adjacent undisturbed terrain. It had one, two, or no ditches and these ranged from a few



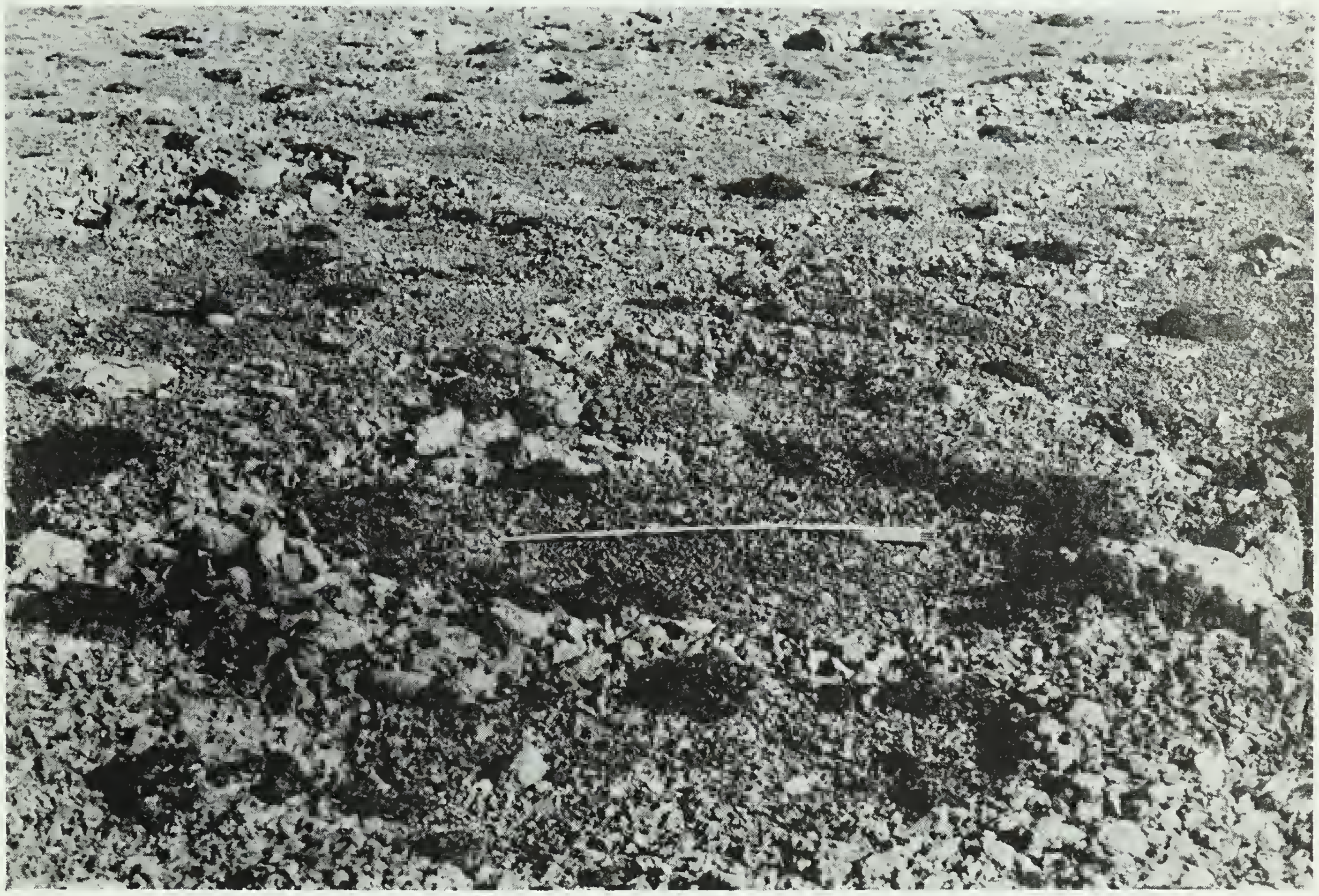
1.9 Decumbent Shrub Tundra: dominated by *Salix reticulata* (50 cm rule)

1.10 Sedge Meadow Tundra: dominated by *Eriophorum* and *Carex* species in flat, wet areas, often with tussocks. This community is extensive on the Mackenzie Mountain Barrens (5 cm interval on range pole)

1.11 Lichen Heath Tundra: dominated by *Cassiope tetragona, Cladonia mitis* and *Festuca altaica* (5 cm intervals on range pole)

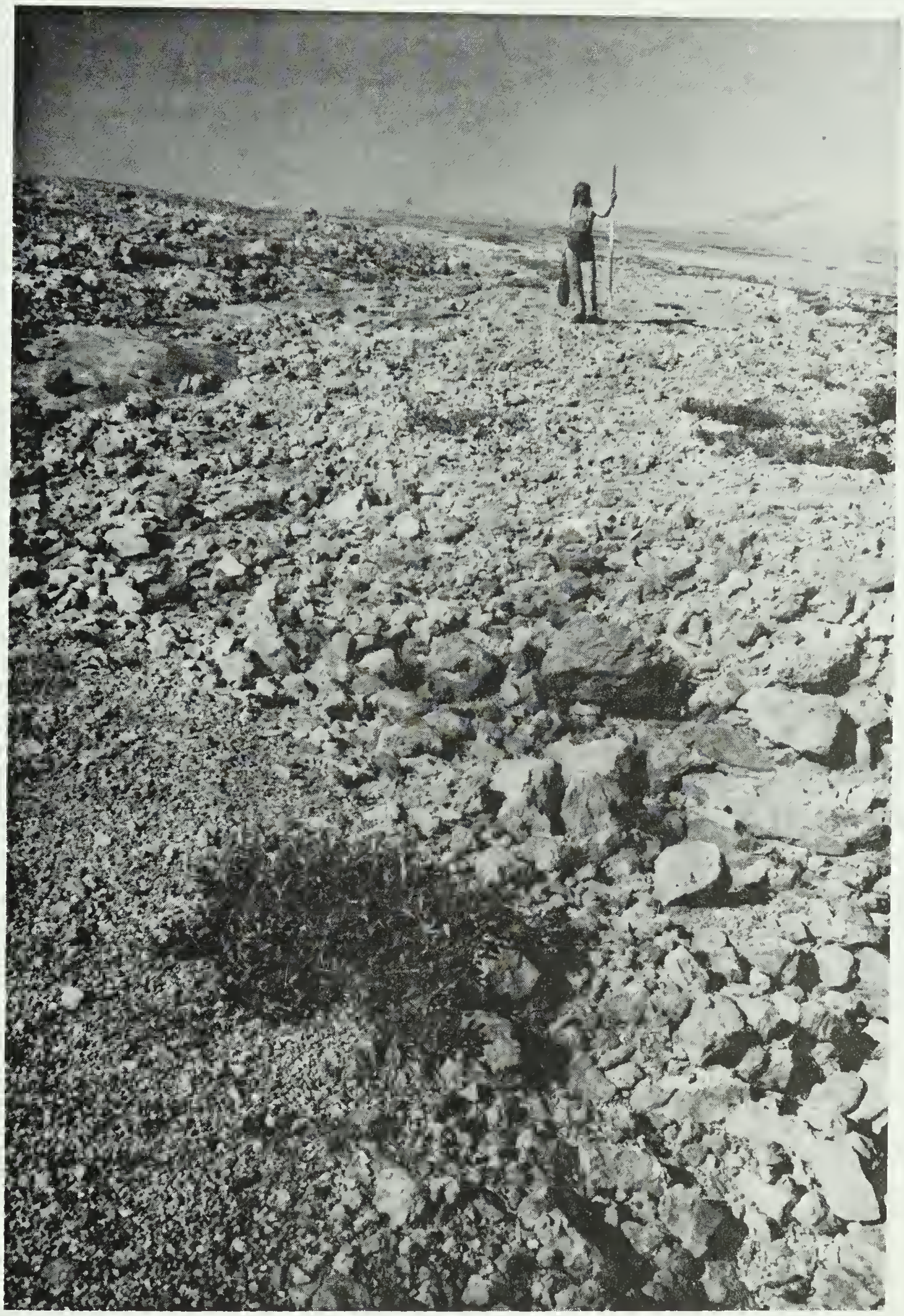


1.12 Fruticose Lichen Tundra: dominated by *Cladonia mitis* and *Alectoria ochroleuca* with *Festuca altaica* clumps. This area, near the Tsichu River, is underlain by a glacial meltwater channel that is delineated by the *Betula glandulosa* shrub cover on both sides (5 cm intervals on range pole)



1.13 Cushion Plant Tundra: dominated by *Dryas integrifolia* and *Salix dodgeana* (100 cm rule). This type of tundra occurs commonly in areas of patterned ground and is depicted here within sorted polygons on the Plains of Abraham.

1.14 Crustose Lichen Tundra: dominates blockslopes on Blue Mountain



1.15 An eroded section of the Canol Road on the Plains of Abraham

decimeters to more than 2 m in depth. On slopes, the road either might be cut into the hillside to form a terrace or built up to produce the same effect. In all cases, it had an aggregate surface but particle size varied with the source material since no crushing or washing facilities were used at the time of construction. The roads were used by heavy machinery, and in most cases, these substrates are now difficult to excavate due to the compaction that resulted from vehicular use.

A number of physical alterations have occurred along the road since abandonment (Figure 1.2). Evidence of thermokarst was found in 56 cases along the road and the majority of these were in the western portion of the study area. A total of 25 bridge washouts was noted. Fifteen debris flows or slumps onto the road were found, primarily where it traversed slopes. In all, 5.3 km of road had been washed out, primarily on the eastern end of the study area. A total of 314 cases was noted where water had been ponded behind the road berm before flowing over and eroding to cause a breach of the the road (Figure 1.2).

False start roads (Plate 1.16) included graded winter roads, poor-weather alternate roads and partly constructed road reroutings. On the last two cases, dumped fill could be found that was never graded. On all such sites, fill was used to provide a road surface but depths of material varied and there was generally less gravel than would be found deposited on a road site. As a result, false start roads were seldom higher than the surrounding terrain and they were rarely ditched. They were infrequently, if ever, used and as a consequence were less compacted than the Canol Road.

Bladed trails were disturbances caused by bulldozers blading the ground to create a level surface (Plate 1.17). The pipeline right-of-way was bladed in many areas to remove shrubs, large stones or hummocks. This produced upturned, organic-rich, border mounds in some areas and left a mineral bed upon which the pipe was laid. In many cases, low spots would be left intact while hummock tops were planed off. The resulting feature was generally a shallow depression dominated by mineral exposures.

Figure 1.2 presents information regarding thermokarst phenomena and overland flow capture initiated by vehicles. This includes the effects of bladed trails and bulldozer tracks. These disturbances have resulted in 61 thermokarst ponds and 79 reroutings of permanent streams or seasonal drainage ways.

1.16 A section of the false start road along the Intga River

1.17 A section of a bladed trail on Blue Mountain, with the windrow composed of larger, upturned stones

Camp yards were temporary or permanent areas used as parking, storage or building sites (Plate 1.18). Generally they were bladed level and seldom infilled but were driven over by tracked and tired vehicles. Construction camps were temporary, with few facilities whereas permanent camps were utilized throughout the life of the Project. Within these areas, relatively undisturbed sites can be found immediately adjacent to highly altered, bladed surfaces.

Bulldozer tracks were identified by the presence of two tread furrows that resulted from compression of the organic horizons during the passage of one or more treaded vehicles (Plate 1.19). These features were apparent most commonly in areas with peaty surface layers. Bulldozer tracks were distinguished on the basis of width, parallel tracking and lack of blading. Their depressions often held ponded water or channelized surface runoff (Figure 1.2). Seventy-nine incidents of this were evident in the study areas (Figure 1.2). As with bladed trails, bulldozer tracks could often be traced for several kilometers using aerial photography. Tracks were frequently observed joining the road to one or more of the other rights-of-way.

Gravel pits were found excavated in glacial outwash, till and modern alluvium as well as in blockfields (Plate 1.20). The term as used here also includes borrow pits in bedrock. Although these were not true 'gravel' pits, they provided aggregate for fill and functioned as gravel pits during the life of the Project. One hundred and eighty-six pits were noted in the study area (Figure 1.2). Of these, 23 contained ponded water year round as a result of local drainage into the closed depression or excavation below the local water table. Pit characteristics varied greatly, ranging from shallow scrapings to steep-walled excavations, 3 m deep.

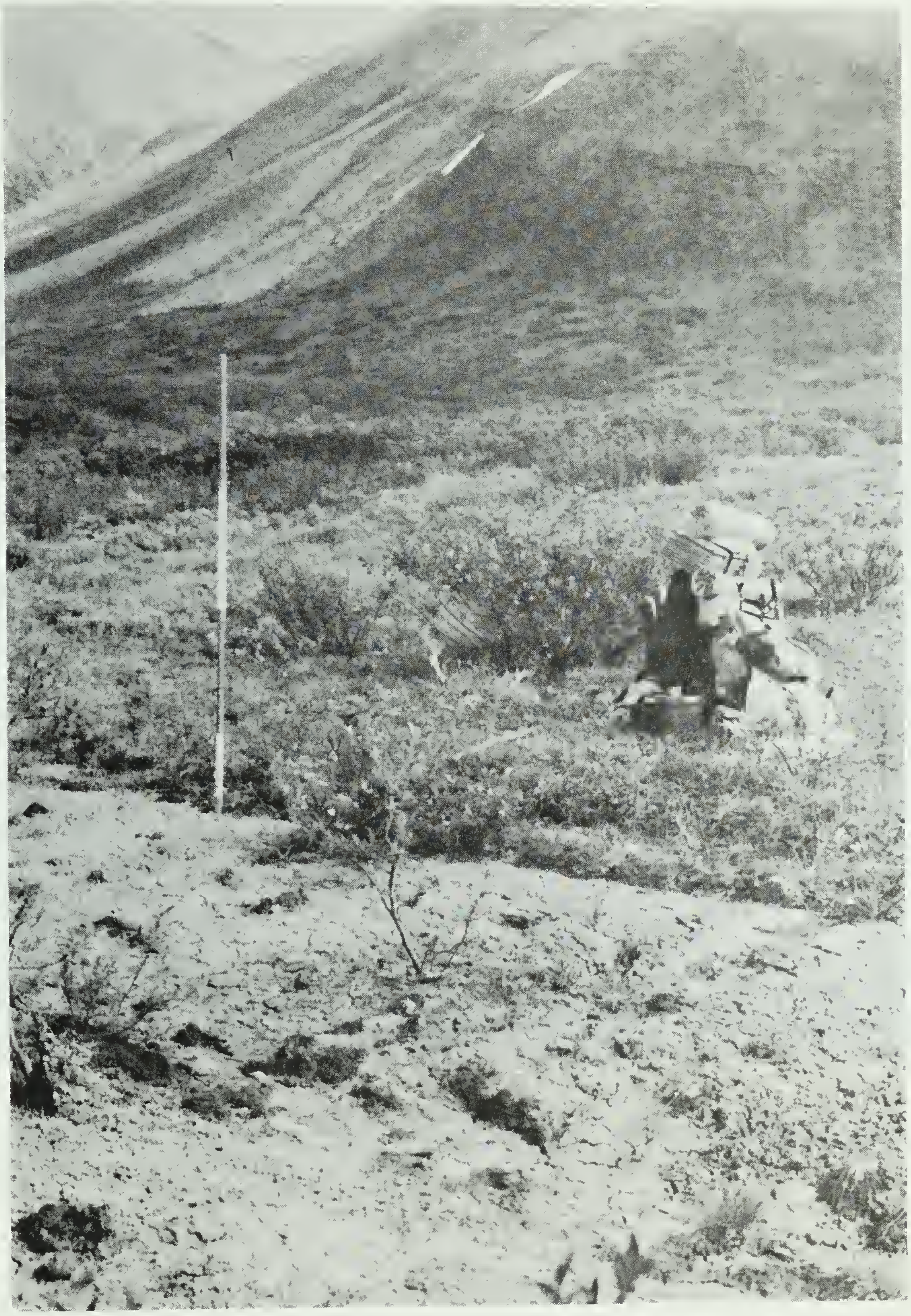
Gravel pit access roads (Plate 1.21), in some cases, appear to be no more than a buildup of material falling from filled trucks as they left the pit. As such they were not ditched and were only roughly graded. Some pit access roads extended more than a kilometer from the road. Surface material was generally loosely compacted and was often rutted by truck traffic.

Oil spills were readily identified by their odour and blackened appearance, and usually lacked plant cover (Plate 1.22). In some cases, these substrates had high organic content but in others, deflation and running water had left only a mineral surface. A thick,

1.18 Camp yard at Pump Station No. 4 (R.M.P. 108). Bolstead Creek is visible in the background.

1.19 Bulldozer tracks across a slope on the Plains of Abraham. Note the greater plant cover in the ruts (50 cm intervals on the range pole)

1.20 Gravel pit with a late snowpatch and ponded water on the Mackenzie Mountain Barrens (50 cm intervals on the range pole)



1.21 Gravel pit access road above the Intga River near Caribou Pass
(50 cm intervals on the range pole)

1.22 Oil Spill in Erect Deciduous Shrub Tundra with a lichen-dominated understory, near Macmillan Pass

waxy or tarry coating was also present on some sites.

1.9 Methods Overview

At least two methodologies could have been pursued in the course of the field studies. The first approach would have involved detailed and intensive sampling along transects over selected disturbances. The objective would be to study the characteristics of certain environmental parameters across a disturbance and to determine the extent of the area now affected by the initial disturbance. This method was rejected for the following reasons: 1) It would be difficult, if not impossible, to determine whether subtle differences between the adjacent zone and the area initially affected were the result of insufficient sampling, natural variability or long-term impacts. 2) Only a few sites could be sampled because of the detailed and time consuming programme required and consequently it would have been possible to study only one or two types of disturbances, plant communities or geographical areas. 3) These relatively minor 'adjacent' effects are less likely to be of concern to residents, legislators or developers and also probably have less ecological significance than do the highly visible impacts that are present on directly disturbed areas. 4) A cursory examination of the study area demonstrates that the greatest alterations are highly localized, often having sharp and abrupt borders (Plates 1.15 to 1.22) This suggests that the most significant impacts were localized and that, although academically interesting and possibly of some ecological importance, the discernible peripheral effects were minimal.

The sampling methodology used was selected as most appropriate for a rapid, extensive survey of the ecological characteristics of CANOL disturbances. Samples were taken in representative areas of disturbances and control or reference areas. The control area was selected as representative of the undisturbed terrain and its characteristics were then compared to those of the nearby disturbances.

A diverse geographical area was subsequently surveyed and detailed sampling was carried out on carefully chosen sites. Sites representative of particular plant communities were selected in an attempt to produce results that could be applied with some constraints to comparable situations in a diversity of northern environments. This methodology is both an asset and a liability. Although the broad sampling programme

facilitated the study of a variety of plant communities, it also reduced the amount of sampling replication that could be carried out during the time available. Consequently, it was inappropriate to employ many statistical treatments of the data which include small numbers of samples for each type of disturbance (e.g. oil spill) within each type of terrain (e.g. Erect Deciduous Shrub Tundra). However, it is felt that the present-day conditions of the sampled sites accurately reflect the type and extent of impacts in the large areas for which they were selected as representative.

A number of methods were employed in this study. These included:

1. field work on the CANOL Project rights-of-way
2. archival research and interpretation of historical photographs
3. a review of published reports
4. interviews with people familiar with the project
5. interpretation of several series of aerial photographs

Detailed descriptions of methods are presented in the appropriate chapters.

Fieldwork totalled 679 man-days in 1977, 1978 and 1979. Of these, 484 involved summer work and 195 were during the winter. Detailed sampling of vegetation was carried out in 1977-1978 and soil and wildlife studies were completed in 1979. The entire study area was covered on foot several times. Consequently, research equipment had to be compact and light. Air support was available only to place food caches and pick up specimens at a few accessible points.

2. HISTORY OF THE STUDY AREA

2.1 Introduction

The detail presented in the following sections provides a comprehensive background on the history of the CANOL Project and an understanding of the initial disturbances. This gives information about the route selection and nature of that decision, the environmental limitations associated with construction in the North and some of the initial consequences of having insufficient environmental baseline information for the job site. The time of year, the type and size of equipment and the frequency and severity of the various impacts must be appreciated if we are to interpret the present-day results and relate these findings to other developments.

The CANOL Project was one of the largest development projects that the Canadian North has experienced. In terms of dollars spent, numbers of people involved, geographical area affected and facilities erected, it may well have been the largest, at least until recently. Cost estimates have been variously placed at $300,000,000 (Legget 1973), $200,000,000 (Neuberger 1948), $138,000,000 (Karamanski 1979), $137,000,000 (Liss 1959), $134,000,000 (Harris 1945) and $130,000,000 (Finnie 1959). Thirty thousand people were employed on the Project (Finnie 1959) which affected an area of over 2.6 million sq km (Meyers 1945)(Figure 1.1).

The CANOL Project was designed to increase the availability of fuel and to provide a secure inland source for military needs in northwestern North America. It was a wartime emergency project and Norman Wells, being the most northerly producing field, met the needs of the military for the defence of Alaska and support of the Northwest Staging Route.

Prior to the initiation of this massive project, few nonaboriginal people had passed through, and even fewer had lived in, the Mackenzie Mountains. Following the CANOL Project, interest in the area increased and there were more frequent visits by nonaboriginal people. Eventually, with the opening of big game hunting in 1965, several outfitters and their staff took up seasonal residence in the area. In 1968, reconstruction commenced on the Yukon section of the Canol Road north of Ross River in an effort to encourage mineral exploration. The following year, summer travel to Macmillan Pass was

possible (Ross River Ferry records). In 1974 AMAX Northwest Mining Co., in co-operation with the Atmosphere Environment Service, established the Tsichu River Meteorological Station. Staff at this station were the only year-round residents in the study area. The station was closed in August 1982.

2.2 Sources of Information

Primary information sources include published material such as Keele (1910), Finnie (1945b), Flood (1946) and Harbottle and Credeur (1966) and unpublished material on file either in archives in Canada or the United States or in private libraries. Unpublished material includes letters, memoranda, diplomatic notes, maps, aerial photographs, consultants' reports and statistics regarding the project. Interviews with people involved in the events of the CANOL Project provided information on particular subjects and were often supplemented by films and photographs. Secondary information sources, though interesting, have not been relied upon to the same extent as primary sources. Appendix I provides greater detail regarding the information sources that were consulted while compiling the following information.

2.3 CANOL 1942-1945

Prior to this period, the only map of any portion of the Mackenzie Mountains was that produced by Keele (1910). No aerial photographic coverage was available for what later became the CANOL route. No aircraft had ever flown directly from Whitehorse to Norman Wells and few native people living at the time had utilized the Macmillan Pass and Continental Divide region. The area of the final route, between the upper Ross River and the Mackenzie River, was virtually unknown and essentially unexplored by anyone, with the exception of a few native people.

2.3.1 Introduction

In the July 1941 issue of *Foreign Affairs*, Vilhjalmur Stefansson suggested that a winter road and/or pipeline be built between Norman Wells and the head of navigation on the Stewart River in the Yukon. He maintained that oil trucked or pumped over this route

could be distributed during the navigation season throughout the Yukon River basin in the event of a military necessity (Stefansson 1941). That possibility became a reality on 7 December 1941 when the Japanese attacked Pearl Harbour. By June 1942, Attu, Kiska, Shemya, and Amchitka (all Aleutian Islands) were occupied (Anon 1980). Hong Kong and Singapore had been taken, Japanese submarines had shelled a refinery in California and shipping losses were heavy with tankers becoming scarce. "The prospect of intensified submarine warfare and the possibilty that it would be concentrated in an attack against coastal tanker shipments became a vital and primary concern"(Public Archives Canada RG36/37 Vol.2 File 3/9).

On 11 February 1942 the Alcan (Alaska) Highway was approved by the US. Army, and by 14 February 1942 directives had been issued for its construction (Truman Committee 1944a). By 7 March 1942, American troops at Dawson Creek had commenced construction of the winter tote road (Truman Committee 1944a). The pioneer road was officially opened on 20 November 1942 and the Alaska Military Highway was completed by private contractors as an all-weather road by the end of 1943.

2.3.2 The CANOL Decision

In February 1941, prior to the demonstrated military necessity of a land route to Alaska and during the planning stages of what eventually was to be the Alaska Highway, Stefansson recommended the Mackenzie Valley–Norman Wells–Fairbanks route (Truman Committee 1944a). On 15 April 1942, he submitted a report entitled *Local Oil Supply, Yukon, Alaska and Bering Sea* to the U.S. Army in which he again advocated use of Norman Wells oil. In this report he included Imperial Oil Limited production estimates of 5,000 barrels *per diem* within 2 years after the drilling of new wells (Stefansson 1942). He also outlined transportation routes over the Mackenzie water route, proposed a winter road and above-ground pipeline over the 'Norman–Mayo portage' and recommended the erection of a refinery on the Yukon River (Stefansson 1942). Stefansson gave a timetable for the movement of supplies and materials and for construction (Stefansson 1942). He noted that a refinery on the Yukon River could distribute refined products via barge in the summer and by truck during the winter

months. The crude oil could be pumped during the winter but the refined products needed warmer temperatures to flow (Stefansson 1942).

With this information, on 20 April 1942 the U.S. "...military authorities made the decision to take advantage of known oil resources in northern Canada for supplying the Alaska Highway and related installations"(Truman Committee 1944a). Five days later, Brigadier General Walter B. Pyron, a U.S.Army petroleum expert, received the information which he requested from Stefansson concerning Canadian sources of oil (Finnie 1959). On 29 April 1942 a two-hour meeting was held at the U.S.Army's request with representatives of I.O.L. and Standard Oil of New Jersey (Truman Committee 1944a). As a result of this meeting, J.H. Graham, Dean of Engineering, University of Kentucky, compiled a one page memorandum which included the following excerpts:

> "To arrange with the company for the drilling of nine additional wells ... production by September ... To build or to otherwise acquire such shallow-draft river-freight craft by June 15, 1942 as may be considered adequate to the circumstances, and to operate these between the railhead, at McMarrys [sic] Waterways, ... to Norman ... To survey by air or ground for a crude oil pipe line to be built on the most direct and feasible route between Norman and the railhead at Whitehorse, the Yukon, Canada; and to arrange for the construction of a 4 inch pipe line on this route (relay pipe is available) with trail connections along the route between pumping stations ... having this pipe line under operation by September 15, 1942. ... oil refining ... minimum extent of 3,000 barrels per day of crude oil refining ... at Whitehorse, The Yukon, Alaska [sic], ... for operation by October 1, 1942."(Truman Committee 1944a).

The memorandum was signed that day by Lieutenant General Brehon B. Somervell, Commanding General, Services and Supply, U.S.Army with a notation "... to take the necessary steps to carry out these recommendations at the earliest practicable date"(Truman Committee 1944a). By the next day, Imperial Oil Limited and Standard Oil of New Jersey had ratified an agreement with the U.S.Army and CANOL was launched (Truman Committee 1944a).

A contract between Bechtel-Price-Callahan (B-P-C) and the U.S. Army for the design and construction of the crude oil pipeline and refinery was drafted on 4 May

1942 and signed on 20 May 1942 (Finnie 1945b). A total of $25,000,000 was requested from the Bureau of Budget, in which the "written justification stated only that complete engineering estimates were not available; that the construction was subject to survey and reconnaissance of the areas involved; that this was a strategic and operational project which had been ordered built as a military necessity; and that it was to be constructed by and under the supervision of engineering troops in accordance with a directive from the commanding general, Service and Supply" (Truman Committee 1944a).

On 15 May 1942, the Canadian House of Commons was informed of the CANOL Project (Unrevised Hansard 15 May 1942) and on May 16, the War Committee of the Cabinet approved the project and granted permission to proceed (Department of National Defense Archives DND348.013 D2). On 26 May 1942, Task Force 2600, consisting of 2,500 men, was activated. This was "a special organization of units proficient in stevedoring and operating barges and pontoons, and placed under Colonel Wyman's command. It included the 388th Engineering Battalion (separate) and the 89th and 90th Engineer Heavy Ponton Battalions, plus signal, quartermaster, finance, and medical units ... The Task Force job was to 'improve transportation' from Waterways to Norman Wells"(Woodman 1977). By 2 June 1942, Task Force 2600 began to arrive at Waterways and soon materials were being readied to move north along the water route.

The War Department had hired Standard Oil of California as an 'expert consultant' and on 4 June 1942, Standard Oil made a report stating that CANOL could not be completed on schedule (Table 2.1). They recommended the shipping of finished fuel products from the south to the Northwest since it would be "... many months before the CANOL Project could be completed"(Truman Committee 1944b).

This was the extent of the pre-planning. In addition to economic, engineering and logistical issues, no environmental concern was expressed and no ecological impacts were considered. The military necessity dictated construction and the decision was taken to proceed after only a preliminary discussion with the oil company and the Canadian Government (in that order).

2.3.3 Ancillary Projects

By 1945, there were six CANOL Projects (Table 2.1) which included docking facilities, barges, tugs, 25.8 km of portage, 2,736 km of water routes, 322 km of summer and 483 km of winter roads around the oil fields, 8 landing strips, 2,415 km of winter roads, 763 km of new all weather road, 2,512 km of pipelines, 763 km of telephone lines and a crude oil refinery (Figure 1.1). The initial directive (cf. Graham memorandum above) did not foresee the extent of the necessary ancilliary projects, nor did it allow for the preparation necessary prior to construction.

2.3.3.1 Ground Route Reconnaissance

Guy Blanchet, an experienced land surveyor, was hired by B-P-C and given the task of plotting the route for the pipeline (Finnie 1947b). On 6 June 1942, interviews with Fort Norman Indians indicated that an Indian trail through the Mackenzie Mountains might be preferable to a Gravel River route. "Their route was a direct one not following any large river and was on hard ground throughout"(Blanchet 1943).

On 25 October 1942, Guy Blanchet with a crew of 6, including Fred Andrew, Little Edward Blondin, Paul (no last name), and George Blondin (all natives from Fort Norman) plus Corporal Ted Bolstad of the RCMP and Joe Saul, set out with 25 dogs along the Indian trail to Sheldon Lake, intending to reach that destination by 1 December 1942. Paul, Joe and Ted returned to Norman Wells after two weeks journey (Blanchet 1942). Contending with a thin, discontinuous snow cover, open rivers, blizzards, -50^{0} C temperatures and scarcity of game, they reached Sheldon Lake ahead of schedule (Blanchet 1942)(Figure 1.1). The route blazed by this team along the 'Indian road' was primarily that followed by the CANOL Project (Figure 1.1).

On 22 December 1942, a reconnaissance survey by tractor train [6] began along the Indian road from Norman Wells (Blanchet 1943). This survey penetrated 170 km (Meyers 1945) or 128 km (Blanchet 1943) [7] before abandoning equipment on 7 February 1943 and returning (Meyers 1945) (Figure 1.1). Another survey departed on 23 March 1943 and advanced as far as Fish Lake, 28 km east of Macmillan Pass. This train covered

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[6]Tracked vehicles travelling in convoy with sledded freight carriers and living quarters in tow.

[7]Finnie believes that Blanchet's figure is the correct one (Personal communication 30 July 1980).

Table 2.1: CANOL Projects

CANOL No.	Project Description	Initial Directive for Date of Completion	Date of Construction Initiation	Date of Construction Completion	Date of Abandonment/ Cancellation
	(where dates vary from one source to another, all are included)				
1	a) Water routes: Docking, portaging, barging and tugs for 1,884 km	15/VI/42	VI/42	end 42	some still used
	b) Mackenzie air route: 8 landing strips	?	?	end 42	some still used
	c) Winter road: 402 km from Fort Nelson to Fort Simpson	?	1/43	1/43	some still used
	d) 1.Tote road:763 km graded, unsurfaced, fine weather road from Norman Wells to Whitehorse	?	10/IX/42	31/XII/43*	30/VI/45
	2.All weather road: 763 km gravel surfaced, maintained road from Norman Wells to Whitehorse	?	10/IX/42	15/X/44+	30/VI/45
	e) Telephone line: approx. the same distance as the road	?	VII/43	10/III/44	30/IV/45
	f) Crude oil pipeline: 10.2 cm line for 737 km and 15.2 cm line for 192 km, welded from Norman Wells to Whitehorse	15/X/42	31/X/42	19/XII/43 (first filled)	13/III/45
			14/VI/43	16/II/44	30/IV/45
	g) Refinery: Whitehorse	1/X/42	?	?	1/IV/45
	Total CANOL No.1 Project	31/VII/42●	?	?	31/III/45
2	Products pipeline: 10.2 cm for 177 km welded pipe from Whitehorse to Skagway	?	18/VII/42	29/XI/42	6/VI/46
3	Products pipeline: 5.1 cm for 430 km, screw jointed pipe from Whitehorse to Watson Lake	?	20/IX/42 (contract let)	16/VI/43 24/VII/43	1/X/45
4	Products pipeline: 7.6 cm for 976 km welded pipe from Whitehorse to Fairbanks	?	22/IX/42	31/VII/43 (first filled) 23/II/44	14/VII/46
5	Products pipeline: Fairbanks to Tanana	25/IX/42	?	cancelled	V/43
6	Winter road:Tractor trail for 1,610 km from Grimshaw to Norman Wells and 322 km from Fort Simpson to Hay River	winter of 42/43	2/X/42	15/VII/42 24/II/43 23/VII/42 1/43	snow-melt 1943
7	Well drilling roads: 322 km summer roads and 483 km winter roads in the Norman Wells area	?	?	?	some still used
8	Tug boats and barges	break up 1943	?	?	?

* tote road complete but all-weather road still under construction when project abandoned
\+ major maintenance was continually necessary to keep the road open, even up to the time of abandonment
● date changed to 31/XII/43 in VII/42

(after Finnie 1947; Hemstock 1945; U.S.Army 1950)

400 km (Figure 1.1) before abandoning equipment on 30 April 1943 to be retrieved the following year (Money 1943). The many difficulties encountered on these surveys are summarized as follows:

> "Diesel fuel froze to the consistency of vaseline, and would not pour. Light motor oil became as hard as cup grease. The best grade of anti-freeze solid in the tins. ... Sleigh runners scraped on the jagged surface and wore out in no time.
>
> Sometimes tractors stopped as often as every fifteen minutes. Intense cold caused condensation. Condensation caused ice. The ice lodged in the fuel system and cut off the fuel supply ...
>
> The cold rendered the sleigh runners as brittle as cast. Time after time they broke. ...
>
> Motors had to be kept running twenty-four hours a day. To stop a motor once and let it get cold meant stopping it for good" (Meyers 1945).

These ground reconnaissance surveys established the general route of the CANOL Project. However, a number of alternatives (Finnie 1947a) were considered before the route was finalized only months before the joining of the rights-of-way on the Mackenzie Mountain Barrens.

It is apparent that equipment and methods employed for similar projects in the south were inadequate, given the rigours of the northern environment. However, lessons to be learned from these reconnaissance surveys were ignored and the Project proceeded.

2.3.3.2 Aerial Photographic Route Reconnaissance

There is confusion over flight line location and dates of the earliest photographic missions. Not all of the photography reported to have been flown can be found today. Sources mention United States Air Force (U.S.A.A.F.) photography taken beginning in April 1942 over an area 320 km wide centering on the Mackenzie River and extending from 80 km north of Edmonton to the Mackenzie Delta (Public Archives of Canada RG 36/37 Vol.4). Another operation in 1942 was carried out by Aero Service Corporation of Philadelphia which photographed the route between Norman Wells and Little Salmon (Public Archives of Canada RG36/37 Vol.4). Woodman (1977) indicated that intensive

aerial reconnaissance began in July 1942. This did not include sequential aerial photography and was probably that which Blanchet reported upon (Blanchet 1943). Lloyd (1944) records that Canadian Pacific Airways photographed the country between Norman Wells and Whitehorse in August of 1942 so that reconnaissance parties could be sent out to select the best route aided by aerial photographs. It is doubtful that this was sequential photography suitable for mapping purposes and no mention of aerial photography was made by Blanchet (1942, 1943, 1944) or Money (1943) prior to or during their October 1942 – May 1943 route reconnaissance surveys (Kershaw 1981). Hemstock reported that he found aerial photographic mosaics at Camp Canol that covered portions of the Eastern CANOL and that some from other sections had been destroyed (Hemstock 1945).

During 6–25 May 1943 Operation Polaris produced trimetrogon coverage from which mosaics were constructed for route selection (Gee 1945) and these were probably what Hemstock saw (Kershaw 1981). The Operation Polaris photography shows much of the final CANOL No. 1 East route prior to construction. However, Bolstead Creek, the Intga River, the Mackenzie Mountain Barrens and Macmillan Pass were not covered (Figure 1.1). Hachured relief maps showing flight lines and image centres were compiled at a scale of 1:63,360 from this photography (A.E.Porsild Map Collection, National Museums of Canada) (personal communication Duncan Campbell, June 1979).

It is apparent that pre-construction preparation was incomplete and that final route selections were, therefore, made on site during construction. It was not until after the Project was operating, that maps and aerial photographic coverage of much of the area were completed. With no familiarity with the environment, no maps and no aerial photography, the construction phase began. No geomorphological, geotechnical or ecological considerations were incorporated into the route selection.

2.3.4 CANOL No.1 East: Construction

2.3.4.1 Road Construction Chronology

On 10 September 1942, road construction on CANOL No. 1 East commenced at Camp Canol (Yukon Archives NNG75.93 No. 13). By 1 October 1942, work had ceased (Yukon Archives NNG75.93 No. 13) but the road was noted as complete to Heart Lake at

R.M.P. 7 on 25 October 1942 when Blanchet's party set out to explore the Indian trail (Blanchet 1942). A further 20.8 km had been cleared and possibly graded when construction stopped (Yukon Archives RG338 No. 1). In December 1942, the decision was made to cease construction until "it should be established that much more oil than has been located as yet is available" (Public Archives Canada RG2,7c Vol.7-17 Roll C-4875; RG24 Vol.2639). At that time the final route had not yet been selected and alternatives were not well known. The changing military situation was a further reason for not proceeding as quickly as possible. The Japanese threat to Alaska was no longer considered as pressing as it had been (Truman Committee 1944a).

Renewed road construction began from the eastern end on 12 April 1943 (Yukon Archives NNG75.93 No. 13). At this time, 'Progress Reports' and 'Charts' were compiled on a weekly basis by the Project's architect-engineers and by the contractors. Not all of these have survived in archival collections but many were abstracted in other available sources. Forty-eight per cent of the 826 km of road construction on CANOL No. 1 East was completed during the winter of 1943-1944.

> "In addition to the construction of road and surfaceing thereof (for 180 miles), 65 pile driven bridges had to be built. This meant cutting of piling timbers and decking in job site saw mills and handling of same over roads which were almost impassable. Eight hundred and twenty culverts, with sizes ranging from 18 to 60 inches [45 to 152 cm] were required. From six hundred and fifty thousand to eight hundred thousand cubic yards [500,000 to 600,000 m^3] of borrow were estimated as necessary for surfacing and filling. Four hundred thousand cubic yards [300,000 m^3] of gravel surfacing were required. It is estimated that in addition to the above mentioned new construction, 250 miles [403 km] of new surfacing were required. This is in addition to spot surfacing, which was necessary in places showing weakness during and following the breakup"(Yukon Archives NNG75.93 No. 16).

Although the construction crews from the east and west met on 31 December 1943, road construction activities continued until the termination of the Project in March, 1945. Officially however, any work carried out after 15 October 1944 was considered maintenance (Public Archives Canada RG24 Vol.2639).

2.3.4.2 Road Construction Methods

The main concerns during construction were engineering problems and efforts to minimize the time required to complete the Project. No references have been noted pertaining to concerns regarding possible environmental impacts.

The initial route was established by Blanchet's dog team traverse and subsequent winter tractor surveys. During construction, the exact road location was flagged by representatives of the architect-engineer and the constructor (Finnie 1947a). J.R. Wells, who had participated in the March-April 1943 tractor reconnaissance guided by Fred Andrew, located the route for the architect-engineer while Andy Hay, a former trapper and prospector, represented the constructor (Finnie 1947a).

In the survey along the easternmost section, tracked vehicles and pack dogs were used whereas in the west, on the Macmillan Plateau (Mackenzie Mountain Barrens), pack horses were employed (Finnie 1947). The use of tracked vehicles caused greater environmental disruption than did the other survey methods and signs of aborted surveys can still be found. Dead end trails and tracks are evidence that a decision was made to select another route.

> "Thus it was that the road was located, with little groups of men poking this way and that ahead of construction, comparing notes, agreeing on one section, disagreeing on another, and making their own sketch maps as they went along – for it was not until the route was far advanced that they were supplied with any aerial photographic strips, and these were incomplete" (Finnie 1947a).

Three crews were employed in road building (Grafe 1943):

1. A pioneer crew cutting a passage just wide enough for equipment, camp sleds and supply trucks
2. A crew widening and ditching
3. A crew surfacing and working to place the road in condition to permit travel at all times.

At least the first crew, and in some cases all three, would have worked constructing false start roads.

Initially construction practices were the same as those employed in more southerly areas, with supervision by engineers trained in the south and with only southern experience. However, ice-rich permafrost was present in many areas along the route and on the Mackenzie Plains the road crossed 37 km of such terrain. Removal of the insulating surface-organic layers caused rapid thawing and loss of the ground's bearing capacity.

> 'I told them to use dump trucks and shove the fill right across the ground without breaking the surface cover,' Andy [Hay] mused. 'Instead, they dozed off the insulation right to the frost and then the fun started. A few hours later there would be a foot or so of mud and the foreman would run a dozer through, and that was kept up until the mud was so high that there wasn't room to displace any more'(Finnie 1947a).

Following this initial experience, practices familiar to people working in permafrost areas were employed. The construction crew "... piled up all the brush and trees cut from the right-of-way to the center of the road, then cut big side ditches on either side, 3 ft. [91 cm] or so deep down to permanently frozen ground, throwing the spill over the trees in the center to form a foundation for the road fill. Stable material was then hauled in for completing the grade"(Richardson 1944b). Inexperience and ignorance increased the time, cost and terrain disruption associated with road building.

> "On the location of the road it is impossible from surface indications to determine the class of digging that will be found, in addition to the fact that the entire area is over permafrost, conditions as to seepage, slides, and ice cap [permafrost], can only be handled as they are met. In numerous cases back up and relocations for considerable distances have been necessary to by pass unstable ground not apparent at the time of location or which developed after the ground was exposed to air" (Grafe 1943).

These relocations and alternate routes added 48 km to the final 444.5 km length of CANOL No.1 East. In the Blue Mountain area, the original road traversed the mountain for 13 km. However, in the winter of 1943-1944, steep grades necessitated relocation of this section and 20 km of winter road was constructed along the Little Keele River. River icings in the winter and ground ice thaw in the summer later prevented use of this

route so traffic was again rerouted to the original road and a further 6.5 km of roadbed constructed across the valley east of Blue Mountain. Six km of road were constructed on the south-facing side of Devil's Pass across from the original route sometime after August 1944 but it is not known if this section was used for any period of time. Four km stretches were commenced on the Plains of Abraham and in the Intga River valley to replace original sections of road but these two false start roads were never completed.

Surfacing materials were brought from the borrow source and pits were used until travel distances became too great. In addition, modern alluvium was mined from river and stream bottoms along the route.

> "From this point (R.M.P. 183) northward this method of construction was largely used as the road usually followed the valley of a mountain stream, the bottom of the valley varying from five to twenty chains in width and being covered with boulders varying from six inches to three feet in diameter. Even where the road followed along a slope on the side of a valley, the material to be moved was usually alluvial soil with boulders or rubble which could be handled by bulldozers without the use of explosives"(Montgomery 1944).

In the higher tundra areas, some modern alluvium was used. However, the majority of the material was colluvium or glacial deposits.

The types and weights of equipment used in these operations included the following:

1. Lin Half-tracks, a favorite in preliminary construction"(Hemstock 1945)
2. D-8 Tractors (18,510 to 19,330 kg), outfitted for various jobs
3. D-7 Tractors (13,970 to 17,090 kg)
4. D-6 Tractors (8,445 kg)
5. H.D.10 Tractors (9,800 kg)
6. D-4 Tractors (5,490 to 6,710 kg)
7. Scrapers (8,935 to 13,835 kg)
8. Tractor Cranes (3,070 kg)
9. Combination Shovel Clam Drags (17,240 to 55,520 kg)
10. Shovels (17,240 to 39,690 kg)
11. A myriad of other equipment ranging from 590 kg welding units to 10,890 kg

trailers capable of hauling 45,360 kg loads (Yukon Archives NNG75.93 No.13)

The D-8's usually pulled two 'cabooses' or 'wanigans' which were portable buildings used for all camp activities. They served as mess halls, work sheds, storage and parts rooms or bunk houses, each holding eight men. These cabooses were mounted on steel-shod sleds and dragged by bulldozer to line camp sites. Such sites were generally convenient locations, close to the work area, which had been leveled off to create temporary camp yards.

The completed Canol Road East was 372 km in length. Road maintenance crews were stationed at camps at R.M.P. 0, 36.5, 50, 74.5, 80.5, 100, 108, 132, 170, 201, 208, and 222. Maintenance facilities included work areas and lodging for crews. Emergency shelters were located along the road at intervals from 5 to 16 km so that drivers would not be marooned without shelter in the event of a mechanical breakdown.

Heavy machinery was responsible for the initial compaction of road materials. However, truck convoys and maintenance machinery passing over the completed road were the major contributors. False start and winter roads were little if ever used and as a consequence were less compacted and displayed greater surface irregularity.

2.3.4.3 Pipeline Construction Chronology

Feeder lines within the Norman Wells oil field were the first pipelines of the CANOL Project. The pipeline crossing of the Mackenzie River was completed 31 October 1942 (Finnie 1943b) and due to breaks, it was shut down 20 November 1942 (Public Archives Canada RG24 Vol.2638). On 14 June 1943, construction of the 10.2 cm (i.e. 4 in) diameter CANOL No.1 East main pipeline commenced (Yukon Archives NNG75.93 No.13). At 2:30 h on 19 December 1943, with 177 km of the pipeline welded, the first oil was pumped into the pipe. At 13:55 h that afternoon, the first oil spill occurred at R.M.P. 18 as a result of pipe that had been damaged by a telephone crew tractor (Yukon Archives NNG75.93 No.11). No complete record of construction phase oil spills has been found but it is certain that many more occurred than were recorded.

Locations and dates of construction indicate that 70 % of the construction on CANOL No.1 East was completed during the winter. On 16 February 1944, the eastern and western ends of the pipeline were joined at R.M.P. 281.5W/R.M.P. 231.8E (Finnie 1947a; Yukon Archives NNG75.93 No.11). Oil passed this point some time between 12

and 20 March 1944 and reached Whitehorse on 16 April 1944 (Finnie 1945b; Public Archives Canada RG36/37 Vol.48). Most construction phase oil spills in the study therefore would have occurred prior to this date. Eleven months later, on 8 March 1945, the U.S.Army issued an order to stop putting oil in the line since the project was to be terminated (Department of National Defense Archives DND348.013 D1; Finnie 1947a:402; Public Archives Canada RG24 Vol.2639 and RG36/37 Vol.6). On 1 April 1945, the refinery ceased operation, having exhausted its stockpiled crude oil supplies (Yukon Archives NNG75.93 No.16).

2.3.4.4 Pipeline Construction Methods

Pipe was received at Camp Canol in 6.7 m (i.e. 22 ft) lengths and double ended in the pipe yard to reduce the amount of welding necessary on the line (Hemstock 1945). Forty such sections could be loaded onto a pipe dollie and trucked to the construction site (Finnie 1947a). The sections were rolled off of the dollie and 'strung' in the approximate area where they would be welded. The pipeline usually followed a more direct route than did the road and the two rights-of-way often deviated from one another by as much as one km. Bulldozing flattened trees and shrubs, smoothing irregular ground along the pipeline right-of-way and red-tipped stakes marked the exact location for the pipeline (Finnie 1947a).

Two types of pipe were used in the line, both of which were considered 'relay pipe' (Truman Committee 1944a). 'Lapweld pipe' was foundry rolled and heated to fuse the metal along its length, whereas 'seamless pipe' was formed as a complete pipe from molten steel in a mould (Finnie, personal communication 1980).

Each 13.4 m pipe section weighed 209 kg (Gray 1970) and was put into position with a D-4 tractor equipped with a side boom (Hemstock 1945). The pipe was placed on wooden blocks to allow access to its underside and the ends were clamped into positon for 'butt welding'.

After welding, the pipe was placed on the ground, sections were blocked off by valves and air was pumped in at 700 kPa pressure to test the welds (Finnie 1947a). Estimates of the labour involved in the various tasks were:

1. 60% for stringing pipe and double-jointing,
2. 30% for welding

3. 10% for testing and completing (Grafe 1943).

As a result of these practices 5 crews, each with at least one bulldozer or tractor and with equipment sleds in tow, passed along the pipeline corridor. All operations were completed over a few days, and unless a rupture of the line occurred, there was no redisturbance of the terrain during the life of the Project.

The pipe was laid on the ground and followed the local topography. This was possible because the oil had a temperature pour point of less than −56.7°C and had a viscosity of 275 seconds (Truman Committee 1944a). It was assumed that an above ground pipe did not need expansion joints and was not threatened by frost heave–induced breaks as buried pipelines might be (Finnie 1945b).

At small streams, the pipe was given anchor collars and laid on the stream bed. At large streams or more rapidly flowing water, the line passed over the water on special pipe supports, on road bridges or on pipeline supension bridges. At the Mackenzie River, the pipe was anchored to the bed of the river in an effort to reduce breakage due to wear against river bed obstructions.

Oil was first pumped into the pipe 4 months before the line reached Whitehorse, at which time construction was 370 km east of the Yukon border. Many losses through line breaks and oil spills were never included in volume estimates since they occurred prior to the operation phase. "Oil losses before operation are explained as being practically unavoidable because water could not be used for testing "(Heney 1944). Incomplete records of spills reported during the filling of the pipe and before the line had been completed, indicate that 44 line breaks occurred during that period (U.S.Army 1950). However, no information is available regarding the quantities of oil involved.

The following machinery was employed for this part of the Project construction:

1. D–4 Tractors with Trackson side booms weighing 6,665 kg
2. D–8 Tractors with bulldozers or bushcutters weighing 17,820 and 20,160 kg respectively
3. H.D.7 Tractors weighing 6,125 kg with welding units weighing from 590 to 1,340 kg (Yukon Archives NNG 75.93 No.13)

The CANOL No.1 East pipeline was 357 km in length and had 6 pump stations:

1. Pump Station No.1 at Camp Canol (R.M.P. 0)

2. Pump Station No.2 at R.M.P. 36.5
3. Pump Station No.3 at R.M.P. 74.5
4. Pump Station No.4 at R.M.P. 100
5. Pump Station No.5 at R.M.P. 170
6. Pump Station No.6 at R.M.P. 208

Each station had a pumphouse, storage tank, light plant, mess hall and dormitory and several had additional facilities. A crew of five, including one head operator, three operators and one roustabout, was necessary to operate each station.

2.3.4.5 Telephone Line Construction Chronology

Telephone line construction began at Camp Canol in July 1943 (Public archives Canada RG36/37 Vol.2 File 3/9). The line was in place eight months later on 10 March 1944 and was operating 17 days after that. Twenty-four per cent of the CANOL No.1 East telephone line was complete by November 1943 and the remainder was finished during that winter.

2.3.4.6 Telephone Line Construction Methods

Telephone line construction had three phases:

1. Route determination
2. Pole setting
3. Wiring.

The route generally followed that of the pipeline but in several sections the two rights-of-way deviated by up to 0.5 km.

As with the pipeline, the right-of-way was cleared using a D-8 tractor to remove brush and trees, levelling the ground and permitting the passage of any following vehicles.

Poles were cut at Fort Simpson and Bear Island (Finnie 1947a) and some were also taken from the area downstream of the Twitya River crossing. In ground-ice areas, dynamite was used to loosen the ground. The construction was labour intensive and tractors were used only occasionally. Flood's journal (1946) describes pole erection by hand and movement of poles from the road to erection sites by horses. The excavation of holes was mainly by hand with dynamiting in ice-rich areas or in bedrock.

"We are having to blast nearly every hole. Most of them are frozen in quicksand, and the blast, to penetrate anywhere deeply enough, has to rip out a regular cavern at the top. The hole my partner and I were on this afternoon was six feet in diameter and three feet deep. We still have to go two-and-a-half feet, and probably will have some hard and slow chipping with the bar near the bottom"(Flood 1946).

Any equipment that was used was similar to that employed in the pipeline construction, with the addition of air compressors to drive drills weighing from 1,475 to 5,785 kg. on bedrock sites (Flood 1946). Few bladed trail disturbances were found in association with the telephone line. However, bulldozer tracks were common in some areas.

The completed line carried two copper-coated, steel wires on a crossbar. Poles were braced at each turn and cross braced in swampy areas. The telephone system was similar in length to the pipeline, with U.S.Army repeater stations at Pump Station Nos. 1, 4, 6, 7, 8, and 10 and at Brooks Brook (Figure 1.1). Each station employed three repeater men and two line men and a roving crew of five was also kept on the system (Hemstock 1945).

2.3.5 CANOL No.1 East: Operation

2.3.5.1 Road Operation

The finished road averaged 4.6 m in width. However, some sections were narrower and others reached widths of 7.3 m. Five per cent of the road had grades of from 10 to 16 % (Public Archives Canada RG36/37 Vol.6).

"Grades often reach eighteen per cent and curves are, for the most part, sharp and unbanked. The fill over muskeg is not deep enough and frost heaving is evident in November. Bridges are wooden pile, bent structures only wide enough for one vehicle, and in several cases, unable to stand ice action in spring. Many culverts are not yet installed. Consequently maintenance is somewhat more difficult than if a finished highway were built"(Hemstock 1945).

From the Mackenzie River to the Yukon border, the road was 372.4 km long (Hemstock 1945:Map). Road maintenance costs were high, estimated at $187,500 a month for the

entire CANOL No. 1 road (Public Archives Canada RG36/37 Vol.6). As mentioned above, numerous sections were rerouted in an effort to reduce accidents and vehicle wear and to increase the efficiency of the transport system (Hemstock 1945). These reroutings were often classified as false start road disturbances, particularly since a number were incomplete at the time of abandonment. Initially, the road was necessary to provide access for the construction of the pipeline and telephone line but with the completion of these lines, the road became a necessary service link for convoys of trucks moving between pump stations and the supply depots at Whitehorse, Johnson's Crossing and Camp Canol. Maintenance of the pipe and telephone lines was carried out from the road which parallelled their rights-of-way. The Canol Convoy headquarters in Whitehorse employed 50 men (presumably the majority of these were drivers) with 40 others responsible for vehicle maintenance (Hemstock 1945).

> "During the winter, snow and icings were the two main problems hindering road operation. 6x6 trucks were handling the job well from 13 camps. Each camp maintained an average of two plows.
>
> In January and February, the work of snow removal became somewhat heavier, necessitating the use in certain areas of caterpillar D-8 bulldozers and rotary plows ... Four Caterpillar Dozers and one rotary plow were based at the maintenance camp at R.M.P. 80.5 to handle the snow on the Plains of Abraham. Four Tractors were based at the maintenance camp at R.M.P. 222 to handle snow in Macmillan Pass ... Snow in other sections was still handled by Galions and truck mounted plows"(Hemstock 1945).

Snow removal with plows often spread surface material from the road top onto the adjacent terrain. In tundra areas, drifting snow accumulated on the road behind plowed snow banks and made removal a continuous job (Hemstock 1945).

Icings developed in winter where water flow from streams, rivers or springs was maintained by ground water sources. They could accumulate on roads or encase the pipeline with several meters of ice. Hemstock described icing conditions which made the road nearly impassable (Hemstock 1945) and Finnie noted a gravel pit excavation, which struck ground-water in winter, where the accumulation of ice extended across the road (Finnie 1947a).

Bridge pilings were tilted and broken by the combined effect of river ice and high spring discharge. The Pelly River bridge was taken out in the first spring following its construction and the Carcajou River bridge and others were also damaged heavily that year. Culverts were plugged by ice and spring melt-water was dammed up or forced over the road causing numerous washouts each year (Public Archives Canada RG36/37 Vol.44 File 19-4-C).

Hemstock recorded that:

> "On the section of road from Canol to Johnson's Crossing, 22 trucks equipped with snow plows were in use during January and February. In addition 15 Galions and 15 D-8 Caterpillars with bulldozer blades were used for snow removal. 15 trucks were in use for glacier control and 7 were used to handle the portable boilers"(Hemstock 1945).

The boiler was an apparatus which emitted steam to melt the ice. Fuel drums containing burning diesel fuel were also used at problem locations in an effort to get rid of icings which progressed too far or too rapidly to be controlled by stoves. Another control method was to raise the road level, keeping pace with ice accumulations (Finnie 1947a).

In the spring, the poor condition of the road rendered it impassable.

> "None of the road was to be passable; much of the previously completed all weather road was washed out or disappeared in muskeg flats; bridges built during the winter [1943-1944] by Bechtel-Price-Callahan in extreme conditions of weather were found inadequate for spring floods and in some cases it was found that some bridges were not even in the proper channels, and these had to be replaced. Bechtel-Price-Callahan was not to be blamed for this, because under winter construction conditions it is often impossible to ascertain the true channel of these turbulent and often changing streams.
>
> Surveys were made covering every mile of the road in early May [1944], as soon as melting of the snow permitted visual analysis. It was necessary to travel 180 miles in the center of the road by tractor and it can be assumed that almost all of this 180 miles was the equivalent of new construction. It was found that the use of the winter road location or even the previous all weather road location was prohibited because the insulating mat

of vegetation had been removed and these road sections became a greater obstacle to new construction than the untouched areas beside them. Unfortunately this condition usually occurred in areas where good [road] material was extremely scarce"(Yukon Archives NNG75.93 No.16).

Hemstock indicated that during the breakup period, 10 April to 10 July, use of the road was restricted to emergencies such as pipeline breaks. Extensive road repairs were necessary following the 1945 breakup before heavy hauling could be resumed that summer and fall (Hemstock 1945).

In summer, dust was a major problem for traffic on the road. Truck convoys on the narrow, twisting road posed a special hazard.

"On meeting any vehicle, as a measure of safety the leading truck driver indicated by the fingers on his hand how many vehicles were in his convoy. So thick was the dust that it was a wise precaution to stop at the side of the road until the convoy had passed .."(Montgomery 1944).

The gravel pit access roads, gravel pits and borrow areas would have been used during this phase of the Project. Consequently, it is difficult to determine which sites were used during initial construction only and were therefore idle after 1943. This is particularly significant in the case of gravel pit access roads, because winter use would have caused less disturbance than summer use.

Few involved in the Project at the time of its initiation foresaw the problems associated with the road. Poorly located stream crossings, thawing of ice-rich permafrost, the break-up of the road in spring, the dust in summer, the extreme cold and snow of winter, and the dramatic changes in elevation with steep grades all combined to make the road an expensive undertaking. The lack of understanding of the northern environment and total lack of preplanning resulted in many costly errors in design and construction.

2.3.5.2 Pipeline Operation

Oil was pumped in CANOL No.1 for a total of 16 months from 19 December 1943 to 1 April 1945. Although oil entered the pipe at Camp Canol in December 1943, it did not reach Whitehorse until 16 April 1944. Delays resulted from construction problems and the time needed to test the pipe for weaknesses. In addition to this, an

estimated 27 days were required to fill the pipe (Yukon Archive RG338 No.4). Oil deliveries were made to Whitehorse for the 331 days from 16 April 1944 to 13 March 1945 (U.S.Army 1950).

Line breaks were a major operational problem. The line was designed to carry 3,000 barrels of crude oil a day. However, at 11,030 kPa pressure, the average daily capacity was 4,200 barrels (Hemstock 1945). Between July and November of 1944, the project provided all of the motor gas requirements for military needs between Watson Lake and Fairbanks and also exported between 136,000 and 244,000 barrels from Skagway. It was projected to produce 53 % of the annual aviation fuel requirements of the local traffic and of some 40,000 lend-lease aircraft which were flown over the staging route to Siberia (Yukon Archives RG338).

Records of the volumes of oil pumped from Camp Canol, received at Whitehorse, used at pump stations, left in the line as pipeline inventory and remaining unaccounted for are available for the period from April 1944 to March 1945 (Hemstock 1945). These data have been summarized in Table 2.2 and, where possible, a summary of the causes of pipeline breakages is presented in Table 2.3.

Only 42 % of the 'Unaccounted For' crude oil losses have been assigned a cause (Table 2.3). Based on volume, 47 % of the oil losses resulted from failure of damaged pipe. Pipe could have been damaged during transport to the job site from manufacturers, during construction or after the pipe was laid on the ground (Hemstock 1945; Heney 1944). The most common cause of such damage was from tractor tread lugs, incurred when the vehicles passed over exposed pipe. "The scars left are points of weakness and have failed under the high pressure and temperature strains encountered"(Hemstock 1945).

A further 22 % of the oil spillage resulted from failure of lapwelds when pumping pressures burst the pipe along the longitudinal joint. The pipe was "... war grade and not uniform to standards for pre-war manufacture" (Hemstock 1945).

Another 12 % of the spills occurred when tension and pressure caused breaks (Table 2.3). Hemstock noted that only a few such breaks were solely as a result of temperature induced tension. On hillsides, the expansion and contraction of pipe in response to temperature fluctuations caused creeping of the pipe and stresses were

Table 2.2: Summary of CANOL No.1 Pipeline operation (barrels)

Date	Total Pumped From Canol	Total Received At Whitehorse	Total Accounted For At Pump Stations	Pipeline Inventory	Total Unaccounted For	% Of Total Pumped
1943						
December 19	4,652	0	ND		ND	
1944						
January	10,458	0	ND		ND	
February	6,827	0	ND		ND	
March	35,554	0	ND		ND	
April	98,053	45,489	ND		ND	
May	81,890	76,399	ND		ND	
Sub-total	237,434	121,988	4,000(est.)	66,964	44,482	18.7%
June	89,725	81,723	758		6,718	7.5%
July	69,322	57,535	1,020		8,552	12.3%
August	89,801	78,963	1,015		11,300	12.6%
September	69,590	61,468	936		9,103	13.1%
October	117,589	109,406	1,084		5,805	3.3%
November	109,824	97,027	1,777		9,224	8.4%
December	106,834	93,324	2,326		5,584	5.2%
1945				Stor. 8,979		
January	120,967	118,448	2,248	Pipe 62,430	3,863	3.2%
				Totl 71,409		
February	106,571	102,287	2,691		4,226	4.0%
March	43,737	49,685	2,553	60,275	ND	
Total	1,161,394	971,685 (83.7%)	20,408 (1.8%)	60,275 (5.2%)	108,857 (9.4%)	

Total Potentially Spilled 108,857 + 60,275 = 169,132 (14.6%)

'ND' no data available (after Hemstock 1945)

Table 2.3: CANOL No.1 Pipeline breaks - Causes and quantities lost (barrels)

Date \ Cause of Loss	Excessive Tension or Pressure	River Washouts	Rock Slides	Unknown	Lapweld	Pipe Damaged	Pipe* Break	Butt Weld	Scraper	Ice Plug	Misc.	Total	Cause of Loss Not Noted (%)
December 1943 to March 1944 - no data available													
1944													
April	0	0	0	0	0	750	0	0	0	0	0	750	NA
May	0	900	0	0	333	3,140	900	0	0	0	30	5,303	NA
Sub-Total												6,053	86%
June	0	0	0	0	0	2,650	10	0	0	0	0	2,660	60%
July	0	0	0	0	2,300	5,050	0	50	0	0	25	7,425	13%
August	0	50	550	0	2,000	2,080	0	1,300	1,750	0	0	7,730	32%
September	0	150	0	0	3,050	3,890	0	0	50	0	0	7,140	22%
October	0	50	0	0	1,890	2,060	0	0	0	0	0	4,000	31%
November	850	0	0	0	650	1,850	0	0	0	2,330	0	5,680	38%
December	2,800	0	0	120	0	250	550	0	0	0	0	3,720	33%
1945													
January	1,700	0	0	0	0	0	0	0	0	0	0	1,700	56%
February to 13 March 1945 - no data available													
Project Totals	5,350	1,150	550	120	10,223	21,720	1,460	1,350	1,800	2,330	55	46,108	
% of Total Recorded Losses	12%	02%	01%	<01%	22%	47%	03%	03%	04%	05%	<01%		

'NA' not applicable

* not noted as a lapweld

(after Hemstock 1945)

substantially increased in such areas.

> "This is especially noticeable between Pump Stations No.3 and No.6, where the line is blown bare for long stretches. Places were seen in February where the line had become so tight that it hung suspended for as much as 10.0 feet across sharp gullies"(Hemstock 1945).

In conjunction with long, steep grades, and damaged, stressed or fatigued pipe sections, the line was operated at pressures higher than those specified by the manufacturer. The probability of a line break at these weak areas increased with higher operating pressures. Hemstock reports that the line was operated at 11,030 kPa, 6.3 % higher than manufacturer specifications, and consequently had a safety factor of only 3.3 (Hemstock 1945).

> "Due to hydrostatic head, a pressure of 1,775 pounds [12,240 kPa] is carried at the Twitya River. This area has caused a great deal of trouble ... There seems to have been an increase, however, in the proportion of temperature stress failures ... steadily worse unless the pipeline is properly anchored"(Hemstock 1945)

A U.S.Army report differs from Hemstock, stating that 104 operational spills occurred (vs. Hemstock's 126) and that 90 % of these resulted from damage by construction equipment while 5 % were lapweld failures, 3 % resulted from temperature induced stresses and 2 % were due to the failure of field welds (U.S.Army 1950).

Hemstock(1945) suggested five reasons for the large amounts of oil lost with most spills.

1. Block gates or check valves were not installed at short enough intervals.
2. In many cases, transportation had been slow and many hours were taken before breaks and valves could be reached.
3. Large temperature changes made breaks hard to detect immediately.
4. Topography of the ground was such that line drain was large.
5. Some difficulty had been encountered with poor gauging and control of the line

A drop in the head pressure at each pump station indicated that a break had occurred. Pressures in the line were then checked in order to locate the spill to within a

few km and this was followed by a visual inspection.

> "Under the existing conditions of installation, terrain, and weather, evidences of line breaks were often difficult to detect, for the magnitude of the station pumping pressure drop resulting from a break was a function of the rate of change of line temperatures as well as of the size and location of the break. In some instances, existence of leaks was not detected until pump station pumpings and receipts and withdrawals along the line were carefully checked"(U.S.Army 1950).

Tractors were used when distances or terrain difficulties restricted access. Repairs were effected using standard welding units, or in winter when transportation was difficult, the pipe was threaded and screwed flanges and spools were used to close breaks (Hemstock 1945). Pipe to be used for repairs was placed on racks above the drifting snow. Breaks under icings or buried beneath the snow were difficult to locate and could also require a long time to repair. New pipe was often laid around the trouble spot in order to reduce the amount of 'down-time' (Hemstock 1945).

Of the oil pumped into the pipeline, 14.6 % was potentially spilled (Table 2.3). This includes the 5.2 % that was left in the pipe and in storage tanks along the line at the time of abandonment. Presumably, much of this was dumped on the ground during salvage operations. The remaining 9.4 % (108,857 barrels) was presumed to be spilled during construction and operation of the line and of this, 42 % (46,108 barrels) was recorded in Hemstock's report with reasons for the various breaks. A total of 30,458 barrels was accounted for (Hemstock 1945). Damaged pipe and constuctional faults led to 54.3% of these losses while operationally induced failures resulted in 39.9% of the oil spillage. Recorded spills represent 42 % of the total losses in the column 'Unaccounted For' on Table 2.3. The remaining 58 % (62,749 barrels) was presumably lost between Camp Canol and Whitehorse. This represents 5.4 % of the oil origihally pumped into the line and such discrepancies were noted during the life of the Project by Hemstock (1945) and Heney (1944). Some of this difference may have been due to weathering, small leaks, poor gauging or unreported use of crude. Weathering losses were estimated to average 1,500 barrels a month (Hemstock 1945) and over the 16 months of operation, weathering could have resulted in a total loss of 24,000 barrels, if this volume could be assumed constant,

leaving a balance of 38,749 barrels 'Unaccounted For'.

Unreported use of crude by constructors and maintenance crews is impossible to assess. A chart from the pump house at Station No.5 had an annotation recording the drawing of crude from the line by Elliott Construction. There is no apparent allowance in Table 2.3 for this use, although it may have been included in the value given for the Pump Stations. The pump station charts also show line breaks which were not included in Hemstock's report and this is certainly another possible source of discrepancy between the volumes 'Unaccounted For' and those recorded as lost in oil spills.

Further operational problems resulted from the poor location of pump station facilities. At Pump Station No.4 the original 1,000 barrel storage tank had to be relocated due to the combined effect of springs, solifluction and ground–ice thaw. Hemstock noted that poor foundation location over permafrost bodies resulted in thermokarst and slumping at some pump stations (Hemstock 1945). The inexperience of contractors and the haste of construction (which was mainly carried out during the winter) most certainly contributed to these problems (Finnie 1947a; Grafe 1943). Oil spills occurred and vehicles had to traverse from the road to repair the pipeline, thereby often creating bulldozer track and bladed trail types of disturbances.

The problems associated with the pipeline operation were primarily the result of a lack of understanding of the northern environment. Costly mistakes resulted from winter construction under extremely limiting conditions, using equipment and techniques designed for less rigorous environments. No northern pipeline had encountered the conditions faced by the CANOL Project. Among the problems resulting from a lack of understanding of northern environments were: the metal fatigue and line creeping resulting from extreme temperature fluctuations, the brittle nature of steel at very low temperatures, the difficulties with vehicular travel over wet tundra when thawed, the degradation of the road during spring breakup requiring the use of tracked vehicles only at that time and the poor visibility and accessibility of pipe encased in icings or buried in snow.

2.3.5.3 Telephone Line Operation

The telephone system operated without major problems. A crew of 5 men was responsible for line maintenance (Hemstock 1945). Stations were 'open' and a coded series of rings was employed to contact each telephone.

2.3.6 CANOL No.1 East: Abandonment

Evacuation directives were issued on 8 March 1945 and the Canol Road East was closed by 24 April 1945. Abandonment was completed prior to spring breakup in order to avoid the delay and maintenance costs associated with keeping the road open during and after spring thaw. Of equal and perhaps greater importance was the fact that the War Department appropriations for CANOL expired 30 June 1945, and in the words of one official

> "...it is not impossible, in view of the changing military picture in Europe and domestic political considerations that Congress may refuse to provide funds for its.continued operation..."(Public Archives Canada MG26 J4 Vol.243 File 2461).

2.3.6.1 Road Abandonment

It was necessary to keep the road open during the shutdown, and evacuation activities centered on road maintenance camps and pump stations. Evacuation moved from the Mackenzie River westward. "Camp R.M.P.35 was closed down on April 5, while the camp at R.M.P.76 was closed on April 9. The schedule calls for the road and camps to be completely abandoned from Canol to R.M.P.280 by April 30,1945" (Hemstock 1945). By 24 April 1945, everything east of R.M.P. 208E was abandoned (Public Archives Canada RG36/37 Vol.6).

Buildings were cleaned, secured and boarded up. Sufficient equipment was left on site to reopen the road, should that be desirable (Yukon Archives RG338). The equipment was winterized and placed in parking areas protected from ice and water action (Hemstock 1945). The heavy machinery too costly to move was left.

"In some cases there is good equipment not near a camp, such as shovels in gravel pits, but this is where the equipment would be used again if the road were opened and it will be left there"(Yukon Archives RG338).

The majority of the rolling stock was brought out (Hemstock 1945; Public Archives Canada RG36/37 Vol.6) but many pieces of machinery were left behind.

"This will leave a great deal of equipment between miles 50 and 280. Such equipment has been rendered immobile through breakage or shortage of parts ... The intention is to abandon the Canol Road completely"(Public Archives Canada RG36/37 Vol.6).

Finally, road blocks were erected at either end of the road (Public Archives Canada GR 22 Vol.109 file 84-32-6 Pt.3) and by 30 April 1945, the road was no longer passable (Public Archives Canada RG 36,37 Vol.6).

2.3.6.2 Pipeline Abandonment

On 13 March 1945, pipeline operations were completely suspended. The pumps were turned off and any oil drain-back was put into storage tanks. A total of 60,275 barrels of oil was left in the pipeline system which included surge tanks at every pump station (Hemstock 1945). Machinery (e.g. pumps and light plants at each station and maintenance camp) was left in grease, winterized and made secure from the weather, ready for the day when it would again be put into service (Public Archives Canada RG36/37 Vol.6).

All of the equipment and machinery necessary to operate the pipeline was left on site since the U.S.Army intended to seek a buyer for the CANOL No.1 Project who would put it back into service as an economic venture. Dismantling of the Project facilities would have lowered its sale value and increased the cost of abandonment. An additional consideration was the spring thaw and the need to withdraw hastily before the road became impassable.

2.3.6.3 Telephone Line Abandonment

The repeater stations were removed from the line as the pump stations and camps were abandoned. This had progressed well by 31 March 1945 (Public Archives Canada RG36/37 Vol.6). The wire and poles were left intact, ready for use, should the

Project be reactivated.

The U.S. Army planned to sell the CANOL No. 1 pipeline to the highest bidder and assumed that the new owner would reactivate the facilities. However, this was not to be the case and instead, much of the oil left in the line was spilled during salvage operations. The vehicles, construction machinery, pump station installations and pipe were the main focus of salvage operations. No attempt was made to rehabilitate any of the CANOL environmental disturbances.

2.3.7 CANOL No.1 East Salvage

2.3.7.1 Salvage Chronology

With the abandonment of the CANOL No. 1 Project in 1945, road blocks were established to restrict access along the Canol Road. Imperial Oil Ltd. acquired title to the assets of the United States Government at Norman Wells for $3,000,000 in September 1945 (Public Archives Canada RG36/7 Vol.2). In 1947, having aquired the salvage rights to the CANOL No. 1 Project for less than $1,000,000 (Phillips 1967; Karamanski 1979), a Pennsylvannia-based salvage firm, L.B. Foster Company (Public Archives RG35 B3 Vol.2126), began removing machinery and pipe from the CANOL No. 1 line. George Prince from Dawson Creek, British Columbia subcontracted to do the work (Public Archives Canada RG35 B3 Vol.2126) and was conducting salvage operations in November 1948. In 1949, Ray Hade and Tom Rimmer from Westlock, Alberta acquired the salvage rights (Anon 1970). Mr. Rimmer took over the operation on the eastern end of the Project in the summers of 1952-1953. Rimmer (personal communication 1978) and Bill Kochan (personal communication 1978) indicated that in 1951 pipe and machinery was removed from the Macmillan Pass area. Although a number of pipe sections still remain, most of the line is gone. Vehicle dumps, barrel caches and camps remain on site, despite the numerous official and unofficial salvages that have been carried out since 1945 (Anon 1970; Synergy West Ltd 1975).

2.3.7.2 Salvage Methods

Salvage work was conducted year-round (Bill Kochan, personal communication 1978), although some sources indicate that a slowdown and/or cessation of activities occurred in the colder winter months and during spring breakup. Apparently, winter operations were restricted to the Yukon portion of the Project, with perhaps some early winter incursions into the N.W.T. before heavy snowfalls occurred (Bill Kochan, personal communication 1978; T. Rimmer, personal communication 1978). The majority of the salvage work on CANOL No. 1 East was completed during the summer months between late June and October(T. Rimmer, personal communication 1978).

To retrieve pipe sections, a low point was selected where initial cuts could be made to drain the oil from the line. The pipe was cut into 12 m lengths, loaded onto trucks and removed. In some cases, the oil was burned and in others it was allowed to drain away from the site (T. Rimmer, personal communication 1978).

Generally, the road was used without attempting to reconstruct or grade it but on large rivers, where fording was precluded, the bridges were made secure. On the Pelly River, crossings were made in winter over the ice and freight was stockpiled at Pump Station No.9. All machinery that was repairable or could be removed in tow was taken out. On the eastern end of the Project, salvage was stockpiled at Camp Canol and later barged up the Mackenzie River (Bill Kochan, personal communication 1978; T.Rimmer, personal communication 1978). The camps, left in readiness for reactivation of the Project, provided a wealth of small articles for salvage.

> "... washing machines, light plants, electric irons, oil stoves, freezers, bed rolls, fuel, double beds, single beds, and inner spring mattresses. There were rations, blankets, pillows, medical supplies, dishes, pots and pans, silverware, and just about anything one could imagine"(Harbottle and Credeur 1966).

Use of the road and pipeline rights-of-way during salvage would have reactivated these disturbances and may well have created new ones. Reference to the August 1944 aerial photography made it possible to determine which disturbances had originated prior to that date but it was not possible to determine whether some had been reactivated during the salvage operations. The most significant environmental impacts associated with the salvage phase appear to have resulted from oil spillage and use of

the Canol Road.

2.4 CANOL No.1 East: Summary

From the time of its inception to its abandonment, the CANOL No. 1 Project spanned 3 years (Tables 2.4 and 2.5). The road was under construction for one month in 1942 and after nine months of work in 1943 was officially declared completed (Table 2.5). The pipeline was under construction for 11 months with eight months of inactivity separating two construction periods (Table 2.5). Two years after its inception, the Project was fulfilling its main objective, delivering crude oil to Whitehorse (Table 2.5). Considering the logistical, environmental and technical limitations encountered during this short period, this was, without doubt, an amazing accomplishment.

2.5 Current Land Use

The North Canol Road [8] in the Yukon was restored during the summers of 1969 and 1970 (Anon 1970). In 1965, the Mackenzie Mountains, N.W.T. were opened for guided sport hunting and three of the outfitting zones delineated at that time included sections of the CANOL Project right-of-way (Simmons 1968b). Outfitting and big game hunting have been conducted in the area since that time.

Facilities installed by the CANOL Project provide easy travel along the road with sure-footing for horses while the buildings give temporary shelter or are used as base camps. Many derelict buildings are used by outfitters and their clients as kitchens, mess halls, bunk houses, storage areas or stables. Four-wheel-drive vehicles can be driven beyond the Intga River and the road is open to regular summer traffic from R.M.P. 231, the Yukon border to R.M.P. 222. The remainder of the road bed is used by horses and hikers backpacking their supplies. Between the Godlin Lakes area and Macmillan Pass, trail bikes have been in use since 1973.

Geological exploration began with the opening of the road (Kindle 1945), was active in the border area in 1952-1953 (B.McFadden, personal communication 1978), and has continued to the present as a major activity. Several permanent and seasonal

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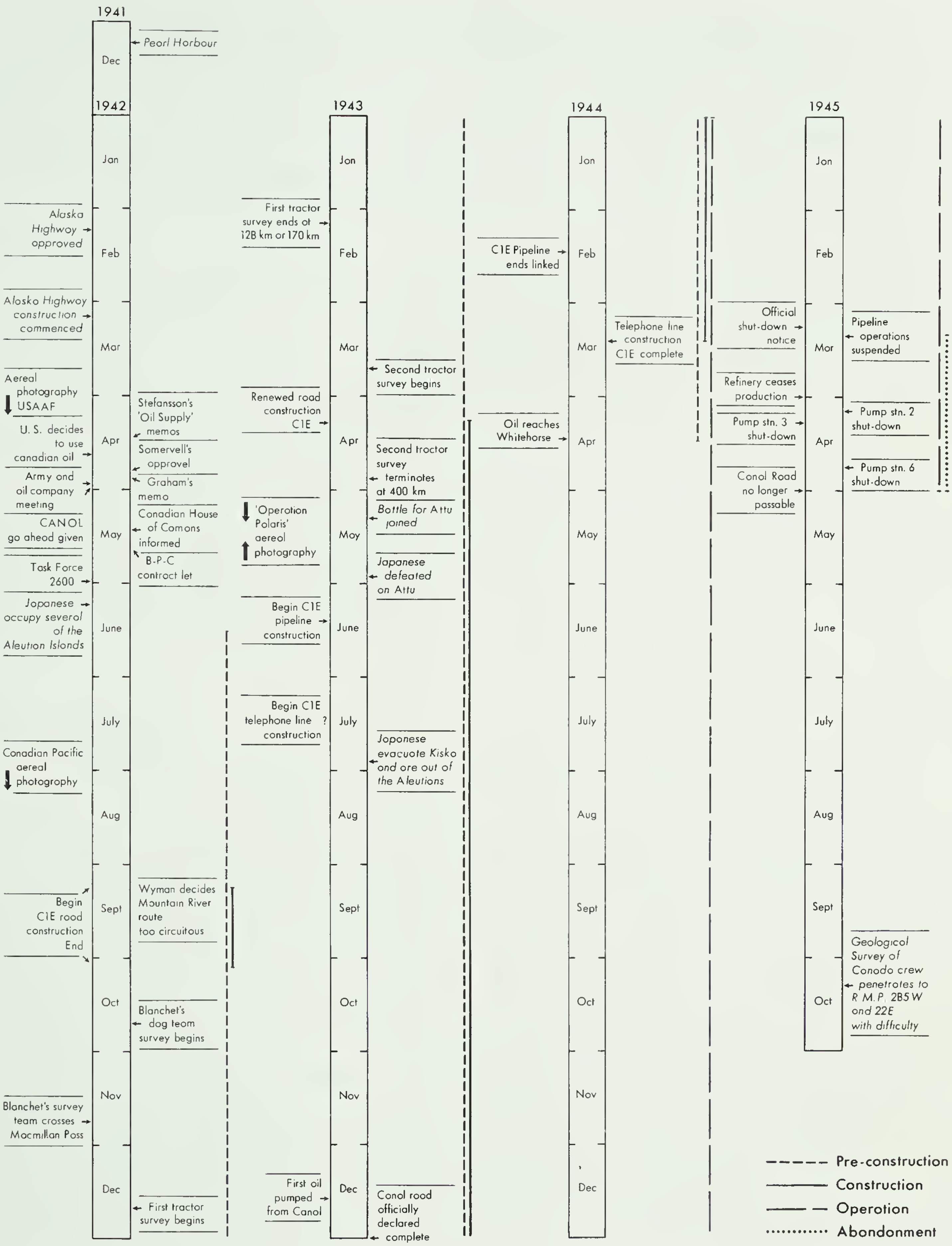
[8]Yukon residents and official Yukon road maps refer to the Ross River-Macmillan Pass section of the Canol Road as the 'North Canol Road'

Table 2.4: Dates of activity and types of disturbances initiated in alpine tundra: CANOL No.1 Project, N.W.T.

Project Stage / Type of Disturbance	Bulldozer Tracks	Bladed Trails	Camp Yards	Gravel Pits	Gravel Pit Access Roads	Roads	Oil Spills
Route Reconnaissance and Survey	1/43-111/43	1/43-111/43					
Road Location Survey	17/VI/43 -1/XI/45	17/VI/43 -1/XI/45	17/VI/43 -1/XI/45				
Road Construction and Road Operation	23/VII/43 -30/IV/45	23/VII/43 -30/IV/45	23/VII/43 -30/IV/45	23/VII/43 -30/IV/45	23/VII/43 -30/IV/45	23/VII/43 -30/IV/45	
Pipeline Construction and Pipeline Operation	1/X/43-31/I/45	1/X/43-31/I/45	1/X/43-31/I/45				25/I/44-31/I/45
Telephone Construction and Telephone Operation	1/XI/43-27/III/44	1/XI/43-27/III/44	1/XI/43-27/III/44				
Project Abandonment			24/IV/45			24/IV/45	
Project Salvage	VI - IX in 1952 and in 1953		VI - IX in 1952 and in 1953			VI - IX in 1952 and in 1953	VI - IX in 1952 and in 1953

sources include various archival documents discussed in the text



Note: Overlap of the pre-construction, construction, operation and abandonment phases occurs since not all the parts of the project were completed simultaneously.
C1E - short for CANOL Pipeline No. 1 East, the Northwest Territories section

Table 2.5 A chronology of CANOL No.1 and related events

camps exist within 10 km of the Canol Road. Seasonal airstrips have been established at R.M.P. 268 and R.M.P. 222. The R.M.P. 222 strip was maintained for ski-equipped winter landings until 1981-1982 and the Camp 222 site had a year-round weather station built into the old camp repair garage. Future developments based on mining ventures seem assured.

In 1979, construction was commenced on a privately owned wildlife lodge in a CANOL Project gravel pit, 0.5 km from the road at R.M.P. 211.8. The buildings, located at the highest point on the Mackenzie Mountain Barrens, were constructed using bridge timbers and telephone poles salvaged from the CANOL Project. A number of windows, doors and sleeping cots from the Project were also used.

Each summer, an average of 6 hikers use the Canol Road and remaining buildings. Some start from the end of the driveable road in the west and hike through to Norman Wells while others begin at various points along the road where they can be dropped off by fixed-wing aircraft or helicopter.

2.5.1 Conclusions

The CANOL Project was one of the largest projects ever undertaken in northern Canada. It was rapidly conceived and executed with little understanding of northern environmental limitations. As a result of inadequate planning and no environmentally sensitive regulation of the Project, its potential for negative environmental impacts was great. For example, the only restriction that was placed on activities during the operation of the Project was a moratorium on hunting and this was apparently ignored (Flood 1946). No mitigative measures designed to reduce environmental impacts were undertaken, except as they resulted from normal engineering practices. No attempt was made to bypass ecologically sensitive areas in an effort to reduce potential negative biological consequences and no rehabilitation programme was instituted to enhance recovery. At at the time of this study the CANOL disturbances were 34-36 years old.

3. SOIL ALTERATIONS RESULTING FROM CANOL DISTURBANCES

3.1 Introduction And Purpose

This portion of the study was concerned with the differences between control soils and disturbed site substrates and whether the magnitude of the alterations varied with the type of disturbance (i.e. purposes 2 and 3 in Section 1.3). Results of this analysis may provide explanations for the local plant community and wildlife characteristics discussed in Chapters 4 and 5.

The term 'substrate', as it is used in this chapter, refers to the surface and near surface layers of the ground (Agriculture Canada 1976). It includes 'soils' of both disturbed and control sites. On the disturbed sites, the newly created surface, immediately following the abandonment of the CANOL Project, had the most direct effect on plant colonization. The surface was the seed bed on which germination and initial survival depended. However, once established the plants' roots would penetrate the surface layer and gain nourishment from a greater depth. Discussion in this chapter will be concerned primarily with the uppermost sections of the substrate.

Disturbances initiated by the CANOL Project have resulted in a variety of substrate alterations. In some cases, near-surface characteristics have become totally different. For example, aggregate extraction has often removed surficial deposits leaving only parent material exposed to be colonized by plants. In other cases, alterations are almost indiscernible. Examples of this were found in areas that had experienced the single passage of a tracked vehicle during the winter. This had only a minor impact and was generally difficult to locate on the ground without aerial photographs and then often was evident only because of vegetation differences (e.g. when erect shrubs had been removed). Exceptions to this were found in tall shrub-dominated areas where clearing had occurred. Oil spills presented yet another case since in these areas substrate alterations were of a chemical as well as a physical nature. Because of the great variety of disturbances, each type has been treated separately within each of the 7 physiognomically defined plant communities.

Surficial deposits reflect the varied geologic and geomorphic history of the region. Parent material characteristics ranged from calcareous to acidic bedrock and

included glacial deposits and colluvium which vary from perhaps pre–Quaternary to Holocene in age. Some surfaces were affected by contemporary permafrost whereas others experienced only seasonal freezing. The eastern portion of the study area was dominantly well drained and gravelly, whereas, the western area had more poorly drained, fine textured surficial deposits and ground–ice was common.

3.2 Methods

3.2.1 Field Methods

Field sampling was carried out between 23 June and 29 September 1979 on those sites where vegetation information had been previously collected. Two criteria were used in selecting representative disturbance sites for sampling.

1. A variety of sites had to be located in close proximity to one another
2. Each set of sites had to be contained within an area of homogeneous vegetation (i.e. in terms of structure and species composition), considered representative of larger regions.

Complex relief often resulted from surface stones, hummocks, tussocks, polygons, circles, nets, steps or stripes. Where applicable, a random sample of individual relief elements (e.g. height, diameter, trough width, riser height, tread length) was measured to the nearest 0.5 cm. Geomorphological features were described and classified for each site with general comments regarding predominant geomorphic phenomena and processes operating recently and in the distant past. [9]

Control or reference sites were selected from nearby undisturbed areas. The control soil pit was dug within the plant community in which the initial disturbance was effected. One pit was dug on each disturbance and its control site to the maximum rooting depth or, in some cases, to the permafrost table or bedrock. No pits were dug in blockfields or, for obvious reasons, in bedrock. Where patterned ground was present with plants on only one portion, the area with vegetation was excavated and sampled. However, when both portions of the feature supported plants, composite samples and

[9] This designation was based primarily on plant cover. Areas devoid of plants were assumed to have been active recently while continuous, well–developed plant cover was taken as an indication of inactivity.

descriptions were made. With few exceptions, all pits for one site (control plus disturbances) were dug and sampled on the same day. Exposures were made large enough to allow a description of lateral and vertical development and to provide sufficient material for samples.

Horizons and the anthropogenic layers (man-made surface deposits or artifically exposed subsurface mineral material) were numbered and each measured to the nearest 0.5 cm. Average thickness and maximum variation were noted. Bimetallic dial thermometers were inserted in the pit bottom and in the centre of each horizon. One also was placed on the ground surface out of direct sunlight. These thermometers were read to the nearest 0.5 C^0. Depths were noted and temperatures were read as soon as the themometers had stabilized. All temperatures for a set of disturbances and their control were determined over a maximum of a few hours time on the same day in order to ensure that they were comparable. A subjective texture assessment was made for each layer with a percentage estimate of clay, silt, sand and stones (these values were later compared with the results of sieving). Where possible, the source of the parent material was noted (e.g. till, colluvium, alluvium, fractured bedrock). Colour was described under field conditions using a Munsell Colour Chart.

Samples of the material that was less than 2 mm in diameter were collected from each layer, sealed in polyethylene bags, frozen and transported to Edmonton for laboratory analyses. Double and triple bagging was used to reduce moisture loss.

3.2.2 Laboratory Methods

Frozen samples were thawed and the moisture content determined gravimetrically (modified from McKeague, 1976:43 and Kalra 1971:67). Moisture content was expressed on an oven dry weight basis. Organic matter was determined by weight loss-on-ignition (modified from McKeague 1976:155 and Kalra 1971:20) and expressed as a percentage of pre-combustion weight. The pH was measured in a soil paste using a combination electrode. Particle size was determined using sieves 10,40, and 200 with mesh sizes of 2.0, 0.42 and 0.074 mm respectively (McKeague 1976:29). Sieving separated four soil fractions: 1) gravel, 2) very coarse to medium sand, 3) medium to very fine sand, and 4) very fine sand, silt and clay (McKeague 1976:5).

Using standard techniques (Jobson et al. 1972), hydrocarbon residue analyses were completed by the Department of Microbiology, University of Alberta for samples collected from ten oil spills. The weight of extracted oil was expressed as a percentage of the total sample weight and n-alkanes (saturated hydrocarbons) were identified using gas liquid chromatography.

3.3 Results And Discussion

In total, 132 substrate descriptions were made from 33 sampling localities with 33 control soil descriptions. The substrate sampling followed 2 years of investigations during the growing season and winter and choice of sites was based on these studies. Sites were chosen as representative of larger areas rather than as random samples for use in statistical analysis. The substrates described represent 43% of the 310 stands from which plant community information was collected. False start roads and recently undisturbed camp yards are not common and as a result only a few were sampled (Table 3.1).

Many of the sample sites were on parent materials exposed during the Project. These often gravelly substrates were therefore relatively sterile environments, and consequently characteristics such as moisture retention ability would be most important in determining suitability for revegetation (Johnson 1981 and Johnson et. al. 1981).

The parameters chosen for study do not necessarily reflect the degree of substrate disturbance associated with oil spills. The addition of oil has altered the substrate by introducing substances toxic to plants and thereby dramaticaly affecting rates of revegetation. Such substances are not found in the other types of disturbances and undoubtedly will effect recovery along different channels. For example, organic content is not the major limiting factor on oil spills but is generally very important on other types of disturbances. Oil spills therefore will be discussed separately.

Initial analyses were based upon mean values for each parameter. This limits discussion to differences between means of controls and disturbances and among disturbances. With the small sample size and the absence of information for all disturbance types in every plant community a further limitation was placed upon interpretations of mean values. In an effort to reduce these problems a

control–corrected value (CC) was derived whereby

$CC = [(D_1-C_1) + D_2-C_2) ... + (D_n-C_n)] / n$

D_1 is the value for a parameter measured in a disturbance at site number one

C_1 is the value for the same parameter measured in the undisturbed (control) area at site number one

n is the number of sites sampled.

Control–corrected values are, therefore, the means of the differences between disturbances and associated controls.

Within the 7 major physiognomically defined plant communties found in the study area, a number of distinctive control soil types can be described (Table 3.1). The specific descriptions presented here are representative of typical soils in these plant communities and where more than one is presented, it is because this plant community was found to occur on more than one soil type.

3.3.1 Erect Deciduous Shrub Tundra

This type of tundra was found to occupy landforms of alluvium and till throughout the study area. However, in the Ekwi–Intga–Tsichu River Valleys Ecosection, the near–surface horizons, predominantly in the tills, were found to be shock sensitive (Zoltai and Woo 1978) and to liquify with a minimum of disturbance. These layers contain 65–70% sand and 30–35% fine sand, silt and clay (Table 3.1). Contact with the gravelly alluvium varied from 7 to 24 cm. Consequently, these soils are generally well–drained. However, the thick surface covering of lichens reduces moisture losses and therefore these soils are also moist (Table 3.2). The sporadically distributed patterned ground appeared to be active. However, to a large extent this was the result of needle ice activity and deflation processes, both of which prevent or restrict plant colonization. Sorted features averaged 100 to 200 cm in diameter and were often contained by a raised, plant–covered border 15 to 25 cm in height. In the Ekwi–Intga–Tsichu River Valleys and the Mackenzie Mountain Barrens Ecosections, a discontinuous volcanic ash layer was often found beneath the organic surface horizon.

Ice–bonded permafrost was restricted to wetlands containing isolated palsas, where organic layers were relatively thick. These features were small in area and the soils

Table 3.1: Soil characteristics of representative control sites in each plant community of the CANOL Project disturbance studies, N.W.T.

Erect Deciduous Shrub Tundra: 75%-100% cover

well-drained river terrace, alluvial parent material composed of shales, slates and sandstones

Soil classification: Sombric Brunisol — Sites: 2,3,9,31,110

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
L-F	5-0	0	0	0		4.3	76	black 10YR 2/1
Volcanic Ash	0-7±3	0	24	76	Ash	5.3	8	yellowish brown 10YR 5.5/4
Ah^1	7-9±2	20	70	30	GSL	4.2	ND	black 10YR 2/1
Ah^2	9-19±1	30	63	37	GSL	ND	ND	very dark gray 10YR 3.3/1
Bm	19-43+	90	93	7	G	4.5	ND	dark brown 10YR 3/3

modern floodplain, alluvium parent material composed of dolomite gravels

Soil classification: Humic Gleysol — Site: 37

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
Ahgk	0-7±5	0	100	0		7.3	11	black 5Y 2.5/1
Cgk	7-30+	75	56	44	VGSL	7.3	ND	very dark grayish brown 2.5Y 3.5

Decumbent Shrub Tundra: 60%-100% plant cover

sorted nets, colluvial parent material derived from dolomites and limestones

Soil classification: Humic Regosol — Sites: 93,94,96,101,112

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
L-F	7-0±6					6.8	54	black 10YR 2/1
Ahk	0-21±6	5	42	58	L	7.0	ND	very dark brown 10YR 2/2
ACk	21-29±2	80	52	48	VGSL	8.1	ND	brown 10YR 4/3

Sedge Meadow Tundra: 65%-100% plant cover

fen, herbaceous peat over till containing shales and slates, permafrost below 60 cm

Soil classification: Organic Cryosol — Sites: 11,16,84

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
Om	60-40	0	0	0		6.9	82	black 10YR 2/1.5
Volcanic Ash	40-38±0.5	0	30	70	SIL	6.4	20	dark brown 10YR 3.5/3
Oh	38-0	0	0	0		ND	87	very dark brown 10YR 2/2
Ahg	0-3	25	53	47	GSL	3.4	ND	very dark gray 7.5YR 3.5/0

Table 3.1 Continued Sedge Meadow Tundra continued

bog, seepage area on colluvium containing granites

Soil classification: Humic Gleysol (peaty phase) Sites: 14,105

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
Om	10-0					4.4	32	dark yellowish bro[illegible] 10YR 3.5/
Ahg	0-16	5	71	29	SL	4.2	14	very dark grayish brown 10YR 3.5/

Lichen Heath Tundra: 80%-100% plant cover

well-drained colluvium parent material derived from granites

Soil classification: Dystric Brunisol Sites: 104

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
Of	5-0	0	0	0		4.2	88	very dark brown 10YR 2/2
Ahg	0-1±0.5	0	85	15	LS	3.9	3	dark brown 7.5[illegible]
Bm[1]	1-29±5	1	74	26	SL	4.2	ND	dark brown 7.5YR [illegible]
Bm[2]	29-44±5	85	82	18	VGLS	4.0	ND	dark brown 7.5YR [illegible]

Fruticose Lichen Tundra: 75%-100% plant cover

well-drained colluvium, parent material derived from granites

Soil classification: Dystric Brunisol Sites: 78,107

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
L-H	2-0	-5	0	0		4.3	35	black 5YR 2.5/1
Ah	0-4	20	80	20	GLS	5.0	5	dark reddish gray 5YR 4/2
Bm	4-25	35	69	31	GSL	4.8	2	dark reddish brown 5YR 3/3

well-drained colluvium, parent material derived from granites

Soil classification: Humic Regosol Sites: 72,76

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
L-F	13-8±4	0	0	0		4.1	100	
H	8-0±3	0	40	60		4.1	77	10YR 4/3
Ah	0-9	90	0	100	G	4.3	ND	10YR 2/2

Cushion Plant Tundra: 3%-35% plant cover

well-drained colluvium, parent material derived from limestones and dolomites

Soil classification: Humic Regosol (lithic phase) under *Dryas* mat Sites: 83,87,88,89,91

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Matter (%)	Colour
Ahk	0-12	25	61	39	GSL	7.2	ND	very dark brown 10Yr 2/2
Ck	12-16	98	91	9	G	7.9	ND	dark brown 10Yr 3/3

Table 3.1 continued Cushion Plant Tundra continued

well-drained colluvium, parent material derived from limestones and dolomites

Soil classification: Orthic Regosol (lithic phase) under bare areas Sites: 83,87,88,89,91

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt, Clay	Texture	pH	Organic Content (%)	Colour
BCk	0-11	20	88	12	GLS	7.9	ND	brown 10YR 4/3
Ck	11-17	98	91	9	G	7.9	ND	dark brown 10YR 3/3

Crustose Lichen Tundra: 70%-100% plant cover

excessively drained blockslope with isolated (5%) pockets of fines, calcareous Sites:

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt,Clay	Texture	pH	Organic Content (%)	Colour
C	0-56	3	56	44	SL	7.1	1	dark brown 10YR 3/3
C	ND	100	0	0	NA	7.1	0	dark brown 10YR 3/3

excessively drained blockslope with isolated (5%) pockets of fines, acidic Sites: 75,98,103

Horizon	Depth (cm) - Range	Particle Size (%) +2mm	Sand	Fine Sand, Silt, Clay	Texture	pH	Organic Content (%)	Colour
C	ND	100	0	0	NA	4.8	1	reddish brown 5YR 4/3

C: Clay G:Gravel L:Loam S:Sand Si:Silt VG:Very Gravelly

ND:No Data NA:Not Applicable

were classified as Organic Cryosols.

Dystric Brunisols were most common in this plant community and were typically found beneath *Betula glandulosa*- and *Salix planifolia*- dominated sites. *Salix alaxensis* was the dominant shrub in riparian plant communities with Humic Gleysol the dominant soil (Table 3.1). Understory plants were dominantly fruticose lichens of the genera *Cladonia, Cetraria* and *Stereocaulon*. Bare ground generally accounted for less than 15% of the total area and was restricted to fine materials in areas of patterned ground.

Twenty-eight samples were taken in this plant community, including 6 control sites and representatives of all 8 disturbance types (Table 3.2). A number of relationships are apparent. The large difference in moisture content between controls and disturbances probably resulted from the much higher gravel content and lower organic matter content on the disturbances (Table 3.2). The lower moisture content, combined with less organic matter has resulted in disturbances having warmer subsurface temperatures. With the exception of false start roads, rooting depths are shallower on all disturbances. This could be a response to the relatively short period (34-36 years) that roots have had to penetrate the ground. Alternatively, the plant species growing on the disturbances may be more shallow rooted than those on undisturbed terrain.

It is apparent from Table 3.2 that bulldozer tracks and oil spills were most similar to the controls, a result of the limited initial disturbance on these sites. The gravel pit access road had 79% of the mean control organic matter (Table 3.2). However, the actual difference from its associated control was only 6% (Appendix II). The mean amount of substrate fines appears to have been changed little by the disturbances (Table 3.2) but when control-corrected data are presented, the results indicate much more variability (Appendix II). Both analyses indicate that the gravel-dominated disturbances provide dryer, warmer substrates. Even those disturbances that have left the pre-existing soil relatively intact have warmer, drier substrates (Table 3.2; Appendix II).

Initially, all of the disturbances removed the shrub canopy. Even without the addition of gravel or excavation, increased exposure to sunlight would result in greater surface warming and greater advection of these areas with a consequent removal of moisture from the surface. When combined with improved drainage (both surface and

Table 3.2: Substrate characteristics of CANOL disturbances, N.W.T. in Erect Deciduous Shrub Tundra

Substrate Characteristics	Control in SB	Control in HG	Road over SB	Road over HG	False Start Road over SB	Bladed Trail in SB	Bladed Trail in HG	Camp Yard over SB	Bulldozer Track over SB	Gravel Pit in SB	Gravel Pit in HG	Gravel Pit Access Road over SB	Gravel Pit Access Road over HG	Oil Spill on SB
pH	4.8	7.8	5.7	7.8	5.7	4.4	7.8	4.6	4.4	6.3	7.1	7.6	6.8	4.0
Organic Content (%)	70	11	4	0	5	5	0	8	43	2	14	55	11	75
Moisture Content (%)	215	26	10	7	13	10	20	16	80	8	35	9	26	68
Gravel Content (%)	3	0	75	60	40	52	70	50	0	58	0	90	10	10
Coarse to Fine Sand Content (%)	80	56	80	89	63	84	66	72	65	88	37	85	58	67
Very Fine Sand, Silt Clay Content (%)	20	44	20	11	37	11	34	28	35	12	63	15	42	33
Temperature at -10 cm (°C)	9.4	13.1	14.7	16.1	13.0	13.6	15.3	12.6	10.5	16.2	14.3	13.9	13.7	11.0
Maximum Rooting Depth (cm)	42	30	18	18	45	25	33	15	27	16	20	17	20	24
n	5	1	4	1	1	3	1	1	3	4	1	1	1	2

SB: 'Sombric Brunisol' HG: 'Humic Gleysol'

internal), these factors result in dramatic substrate differences between controls and their associated disturbances (Appendix II) and between the mean values for substrate characteristics on all controls and disturbances in this plant community (Table 3.2).

3.3.2 Decumbent Shrub Tundra

This plant community was most common in the eastern portion of the study area, principally on landforms composed of colluvial and alluvial deposits. Parent materials were generally calcareous (Table 3.1). The nine samples of control soils in this plant community were classified as Humic Regosols due to their poorly developed structure. Organic surface layers were thin and all profiles were very gravelly. These soils were well to excessively drained as a result of their high gravel content and low water retention potential. Soil characteristics varied little from site to site.

Generally these soils occurred within extensive areas of patterned ground in unglaciated terrain. However, no permafrost was encountered and it was concluded that the shallow lithic contact (i.e. within 2 m of the surface) in conjunction with seasonal frost action or the preservation of fossil periglacial features acconted for their presence. Non-sorted steps had risers averaging 15 cm in height with treads between 50 and 160 cm in length. Sorted nets had riser borders averaging 13 cm in height and diameters between 40 and 140 cm. Solifluction lobes were present and often the small scale patterned ground was superimposed on them.

Species of the genera *Dryas, Salix* and *Potentilla* were the dominant plants. Total plant cover varied from 60 to 100%. Areas with active needle ice, deflation or seasonal frost churning processes were devoid of plants.

A total of 7 disturbance types were described in this plant community and 35 substrate samples were taken (Table 3.1). The higher pH values on most disturbances (Table 3.3) indicate either that the fill or the material exposed by excavation was composed of more calcareous lithologies and that these surfaces had less of the acidic organic matter. All disturbances, with the excepton of oil spills, had less organic matter than was found in control substrates. However, it is noteworthy that over the past 34 to 36 years, disturbances which totally covered or removed the pre-existing soil (i.e. roads, false start roads, gravel pits) have accumulated from 64% to 74% of the amount of

Table 3.3: Substrate characteristics of CANOL disturbances, N.W.T. in Decumbent Shrub Tundra

Substrate Characteristics	Control Humic Regosol	Road over	False Start Road over	Bladed Trail in	Bulldozer Track on	Gravel Pit in	Gravel Pit Access Road over	Oil Spill on
pH	6.9	8.3	7.9	7.5	6.8	7.7	7.8	7.2
Organic Content (%)	38	15	0	6	8	0	6	68
Moisture Content (%)	93	55	12	22	32	19	12	54
Gravel Content (%)	18	90	80	70	40	77	72	6
Coarse to Fine Sand Content (%)	47	65	65	63	64	59	51	43
Very Fine Sand, Silt, Clay Content (%)	53	35	35	37	36	41	49	56
Temperature at -10cm (°C)	12.5	22.2	13.6	14.4	13.8	12.8	15.8	14.4
Maximum Rooting Depth (cm)	38	46	15	21	33	15	22	23
n	9	10	1	5	3	8	3	5

organic material found in control areas (Appendix II). The organic matter in undisturbed areas could have accumulated over hundreds or even thousands of years. This relatively rapid rate of organic accumulation may be a result of enhanced production on disturbances or a reduced rate of decomposition. In this environment, where temperature is a biological limiting factor, the warmer substrates of disturbances (Table 3.3) must be a positive factor in plant growth. The shallower rooting depths on disturbances indicate that plants have taken advantage of these warmer substrate conditions. This also suggests that moisture is not a significant limiting factor in this plant community since the organic accumulations produced by the plants on the site have developed despite drier substrate conditions (Table 3.3 and Appendix II). The picture is complicated further by the fact that the drier areas may have reduced rates of decomposition.

3.3.3 Sedge Meadow Tundra

Wetlands were found throughout the study area. However, they were most common in the Mackenzie Mountain Barrens Ecosection. Fens and bogs were sampled and Organic Cryosols and Humic Gleysols were described. The Organic Cryosols had organic layers more than 50 cm thick and a late August thaw layer of 50 to 60 cm. Palsas and peat plateaus were common in these wetlands but generally supported shrubby vegetation.

The Humic Gleysols were peaty and sometimes associated with patterned ground when in till. In these cases, the near surface layers were shock sensitive. However, no permafrost was found at these sites. Non–sorted steps and stripes had raised margins or risers of 20 and 32 cm in height respectively and treadlengths of 200 and 860 cm respectively. Parent materials were generally acidic except at one site on the Plains of Abraham where limestones and dolomites dominated.

Sedges in the genera *Carex* and *Eriophorum* were the dominant plants with underlying mats of *Sphagnum* spp. and *Hylocomnium splendens*. Plant cover on Organic Cryosols was 100% whereas on the Humic Gleysols it was as low as 75%.

Five control and 9 disturbed sites were sampled in sedge meadow tundra, including examples of 5 disturbance types (Table 3.4 and Appendix II). Surface layer thickness on bladed trails and bulldozer tracks was reduced by excavation and

Table 3.4: Substrate characteristics of CANOL disturbances, N.W.T. in Sedge Meadow Tundra

Substrate Characteristics	Control		Road over		Bladed Trail in	Bulldozer Track on	Gravel Pit in		Oil Spill on
	HG	OC	HG	OC	HG	HG	HG	OC	HG
pH	4.2	7.6	6.6	7.4	4.4	4.0	6.0	8.3	3.8
Organic Content (%)	56	54	0	4	100	100	0	6	100
Moisture Content (%)	230	247	19	14	541	261	16	56	42
Gravel Content (%)	1	0	90	80	0	0	30	40	0
Coarse to Fine Sand Content (%)	73	19	82	68	0	0	80	15	?
Very Fine Sand, Silt, Clay Content (%)	27	81	18	32	0	0	20	85	?
Temperature at -10 cm (°C)	8.9	10.1	14.3	15.5	6.9	5.7	12.3	13.3	9.5
Maximum Rooting Depth (cm)	28	36	20	17	24	22	15	33	0
n	3	2	1	2	1	1	1	1	2

HG: 'Humic Gleysol' OC: 'Organic Cryosol'

compaction respectively. As a result, these substrates were wetter and cooler than the mean of the controls (Table 3.4) and than their associated controls (Appendix II). The substrate of the gravel pit appears to have recovered dramatically since its excavation 34–36 years ago. Despite the 40% gravel content (Table 3.4), it has accumulated 98% of the organic matter found in its control (Appendix II). Rooting depth is approximately equal to that of the associated control while moisture content and subsurface temperature are higher (Appendix II). These conditions have enhanced organic matter production and a rapid rate of accumulation. The roads have warmer but drier substrates and have accumulated 50% and 65% of the organic matter found in their controls (Appendix II). Considering the short time interval (34–36 years) and the different environment provided by the disturbance this is a rapid rate of accumulation. Lore (1977) has shown that enhanced annual production of standing crop occurs on 50-year-old cart tracks. Thus rates of organic matter accumulations can be greater than those of controls within 50 years of disturbance.

3.3.4 Lichen Heath Tundra

This plant community was found in the Bolstead Creek–Devil's Pass Ecosection on landforms composed of colluvium. It is not a common or extensive plant community in the study area. Gravel contact occurred at approximately 35 cm depth and was composed primarily of granitic material. Consequently, the substrate pH was low (Table 3.1). No permafrost was encountered in this community. The Dystric Brunisol soil type associated with this plant community supported a plant cover of 90% to 100%. Dominant plants included *Cassiope tetragona* and *Vaccinium uliginosum* with the lichen genera *Cladonia* and *Cetraria* forming mats at ground level. In addition, *Polytrichum* spp. were common.

One set of 4 disturbances with their associated control were sampled in Lichen Heath Tundra (Table 3.5). The rise in pH (Table 3.5) resulted from the burying or excavation and removal of the more acidic surface layer and not from pH changes that had occurred over the 34–36 years since the initial disturbance. The large difference in moisture content has resulted from the greater gravel content on disturbances than in the control substrates. These well-drained materials with low moisture retention were

Table 3.5: Substrate characteristics of CANOL disturbances, N.W.T. in Lichen Heath Tundra

Substrate Characteristics	Control Dystric Brunisol	Road over	Bladed Trail in	Gravel Pit in	Oil Spill on
pH	4.2	5.5	4.3	5.5	4.4
Organic Content (%)	100	2	2	2	0
Moisture Content (%)	270	13	10	10	20
Gravel Content (%)	0	95	55	85	10
Coarse to Fine Sand Content (%)	0	80	76	83	71
Very Fine Sand, Silt, Clay Content (%)	0	20	24	17	29
Temperature at -10 cm (°C)	7.2	15.6	13.4	14.1	13.8
Maximum Rooting Depth (cm)	38	32	23	16	0
n	1	1	1	1	1

warmer because of the removal of the insulating surface organic layer and the reduced moisture content. The thick lichen carpet which graded gradually into the the organic layer on undisturbed sites was removed and no longer acted as a barrier to ground heat and moisture flux. In this plant community, the organic matter accumulation over the 34–36 years since the initiation of the disturbance was very low (Table 3.5). This may indicate that moisture was a limiting factor in this plant community, with the higher substrate temperatures (twice as high as those of the control) causing periods of drought and subsequent mortality of seedlings and/or adult plants.

3.3.5 Fruticose Lichen Tundra

This type of tundra was found on well drained, gravelly landforms composed of alluvium or colluvium. In the Blue Mountain Ecosection, this plant community was found on colluvial deposits whereas in the Ekwi–Intga–Tsichu River Valleys Ecosection it was commonly on eskers and alluvial fans. Near surface, shock sensitive layers were present in the western portion of the study area in Dystric Brunisols. Gravel layers occurred within 10 cm of the surface in all soils sampled (Table 3.1). Non–sorted nets, circles and steps were common in the Blue Mountain Ecosection and were generally associated with Humic Regosols. Large–scale circles and steps had diameters of 5–10 m. However, no permafrost was encountered and the features appeared to be inactive, with 100% plant cover.

Lichens of the genera *Cladonia* and *Cetraria* were the dominant plants and generally formed over 80% of the normally 100% plant cover. Organic layers retained much of their plant structure and it was difficult to determine where live biomass ended and humus began.

Six disturbances were described in areas of Fruticose Lichen Tundra. Four control and 14 disturbed sites were sampled (Table 3.6). The difference in mean pH may have resulted from the burial or removal of the relatively acidic surface layer of the pre–disturbance soil. Bulldozer tracks, which sustained relatively little disruption of the pre–disturbance surface, have pH values that are equal to or only slightly different from the control means (Table 3.6). Mean values for organic content and moisture content indicate that bulldozer track substrates are most similar to the control soil types in this

Table 3.6: Substrate characteristics of CANOL disturbances, N.W.T. in Fruticose Lichen Tundra

Substrate Characteristics	Control		Road over		False Start Road over	Bladed Trail in		Bulldozer Track on		Gravel Pit in		Gravel Pit Access Road over
	DB	HR	DB	HR	HR	DB	HR	DB	HR	DB	HR	DB
pH	4.2	4.6	5.4	5.9	5.4	5.6	5.0	4.2	5.0	4.7	5.9	5.0
Organic Content (%)	68	55	2	1	0	0	0	100	0	1	0	0
Moisture Content (%)	168	180	15	10	7	11	11	67	11	8	10	12
Gravel Content (%)	2	20	90	88	95	65	85	0	85	80	78	75
Coarse to Fine Sand Content (%)	75	87	64	69	84	94	64	0	64	71	62	74
Very Fine Sand, Silt Clay Content (%)	25	13	36	31	16	6	36	0	36	29	38	26
Temperature at -10 cm (°C)	7.8	7.9	13.7	13.2	13.2	15.2	7.5	8.3	7.5	13.9	11.9	13.7
Maximum Rooting Depth (cm)	32	11	26	23	23	17	17	22	17	11	11	13
n	2	2	1	1	1	1	1	1	1	2	2	2

DB: 'Dystric Brunisol' HR: 'Humic Regosol'

community.

Roads in Fruticose Lichen Tundra have 45% to 67% of the organic matter found in both control soil types (Table 3.6) Where a disturbance affected both soil types in this plant community, the differences in organic and moisture content relative to the controls were greater in Humic Regosols (Appendix II), despite the fact that control soil conditions were similar (Table 3.6). In Dystric Brunisols, subsurface temperatures of disturbances were higher than those of disturbances in Humic Regosols. Bulldozer tracks were and exception (Appendix II) but these disturbances had organic matter and gravel content values that were very similar to those of their controls (Appendix II). Rooting depth in Humic Regosols was greater on all disturbances (with the exception of gravel pits) whereas in Dystric Brunisols the depth of rooting was generally less than that of the controls. It is evident that warmer substrates result from the removal or burial of organic surface layers and the insulating lichen surface covering in addition to the deposition or exposure of coarse, well-drained materials.

3.3.6 Cushion Plant Tundra

This plant community was most common on colluvial deposits in the Plains of Abraham Ecosection. The soils were Regosolic with Humic Regosols under plant cover (Table 3.1). These soils were well to excessively drained and gravelly, often with a shallow lithic contact. This combined with their location in the rainshadow of the Mackenzie Mountains, has produced dry soils. Parent materials were calcareous, composed of limestones and dolomites.

Patterned ground was present in all cases. Sorted and non-sorted nets, circles, steps and stripes were common. However, no permafrost was encountered although the features appeared to be active. Features had raised borders of 10–40 cm in height and were from 45 cm in diameter on small features to 10 m long on stripes.

Plant cover values ranged from 3% to 20%. Dominant plants included *Dryas octopetala*, *D. integrifolia*, *Silene acaulis* and *Salix dodgeana*. These plants formed small patches that retained dead leaves and otherwise accumulated organic matter. The L–F layers were found beneath this portion of the surface only.

Five controls and 10 sites representing 4 types of disturbances were described from Cushion Plant Tundra (Table 3.7). The data indicate that many substrate parameters are very similar on disturbed and control sites. The greatest differences observed were in gravel content and maximum rooting depth (Table 3.7 and Appendix II).

3.3.7 Crustose Lichen Tundra

This plant community is most common in the 5 easternmost Ecosections. Substrates can be divided into groups as either acidic or calcareous. Those of both categories were rocky, being found in blockfields or on block slopes. Calcareous substrates frequently had finer material beneath a surface layer of blocks and/or in isolated islands dispersed throughout. All of these areas were classified as rockland since they did not meet the criteria of Regosols (Table 3.1).

The blockfields were excessively drained and lithic contact. was generally within 1 m of the surface. Limestones and dolomites composed the blockfields in the Plains of Abraham Ascent, Plains of Abraham Plateau and Joker Ridge Ecosections but these features were predominantly granitic in the Blue Mountain and Bostead Creek–Devil's Pass Ecosections. If permafrost was present at these sites, it was not ice-rich and it occurred in the bedrock, at depths greater than 1 m.

The presence of 90% to 100% plant cover was interpreted as an indication of surface stability. The dominant species were generally long-lived and slow growing lichens in genera such as *Rhizocarpon* and *Lecanora.* Several species of the Umbilicariaceae were common on siliceous substrates while members of the Lecideaceae were predominant on calcareous materials.

Three types of disturbances were studied in this plant community with a total of 5 samples and 3 controls described (Table 3.8). Moisture content was limited due to a lack of ability to retain water. In the calcareous blockfields this condition was somewhat ameliorated in the localized areas of finer-textured materials (Table 3.8). Most disturbances had more fine-textured materials and therefore had greater moisture storage ability than did their controls (Table 3.8). In the acidic blockfields the surface temperatures were high as a result of their continuous, black lichen cover. Disturbances were lighter in colour, with a higher albedo and therefore had lower surface

Table 3.7: Substrate characteristics of CANOL disturbances, N.W.T. in Cushion Plant Tundra

Substrate Characteristics	Control Regosol	Road over	Bladed Trail in	Gravel Pit in	Gravel Pit Access Road over
pH	7.8	7.6	7.8	7.4	8.0
Organic Content (%)	3	0	0	0	0
Moisture Content (%)	20	12	11	5	23
Gravel Content (%)	13	70	75	95	75
Coarse to Fine Sand Content (%)	62	63	38	66	31
Very Fine Sand, Silt, Clay Content (%)	38	37	62	34	69
Temperature at -10 cm (°C)	10.3	12.4	9.4	10.6	9.2
Maximum Rooting Depth (cm)	27	13	26	4	15
n	5	4	2	3	1

Table 3.8: Substrate characteristics of CANOL disturbances, N.W.T. in Crustose Lichen Tundra

Substrate Characteristics	Control Rockland Acidic	Control Rockland Basic	Road Acidic	Road Basic	Bladed Trail Acidic	Gravel Pit Acidic	Gravel Pit Basic
pH	5.1	7.1	7.6	8.1	5.4	4.8	7.7
Organic Content (%)	1	1	0	0	1	1	0
Moisture Content (%)	0	22	9	11	0	10	10
Gravel Content (%)	100	3	90	95	100	98	90
Coarse to Fine Sand Content (%)	0	56	74	58	0	77	61
Very Fine Sand, Silt, Clay Content (%)	0	44	26	42	0	23	39
Surface Temperature (°C)	20.8	11.9	13.4	11.0	12.9	10.3	11.0
Maximum Rooting Depth (cm)	0	26	15	25	0	15	0
n	2	1	2	1	1	1	1

temperatures (Table 3.8; Appendix II). These conditions offered a much less harsh environment for vascular plants on disturbances than on controls. The high temperatures and low moisture of control substrates would create water stress conditions for most vascular plants and disturbances would provide a more habitable environment. The fine materials found on disturbances provided a rooting medium for vascular plants that was absent in undisturbed areas. The localized accumulations of fines in calcareous blockfields where vascular plants were established, had rooting depths similar to those found on disturbances (Table 3.8). This observation supports the conclusion that the limitation to vascular plant growth in this community was a lack of suitable rooting medium.

3.3.8 Oil Spill Disturbances

The type and amount of oil residue remaining in the soil varied from one oil spill to the next (Table 3.9). All of the oil spills predated May 1945 and the majority occurred in 1944.

It is impossible, with the loss on ignition technique to determine the amount of naturally occurring organic matter on these disturbances. Oil spills were deposited on the ground surface and the soil structure was little altered by the addition of oil. Surface vegetation and organics usually absorbed the oil and have undergone some consolidation over the past 35 years due to the weight of the oil. In Decumbent Shrub Tundra the surface layer pH was, on average, slightly more acidic than the controls (Table 3.2). Moisture content was less as a result of the sealing of the surface by oil. Little water was able to penetrate the surface to be absorbed at depth. In addition, mineral soil spaces would have been clogged with oil to prevent water infiltration (Bliss and Wein 1973). In organic layers, oil was absorbed by the litter which acted as a sponge. This was also noted by McCown and others (1972).

Much of the oil spill analyses in this section has been based upon the presence or absence of n–alkanes or isoprenoides since these are thought to reflect most accurately the rate of natural degradation. Crude oil has four major components: asphaltenes, saturates, aromatics and the polar N(nitrogen)–, S(sulfur)–, and O(oxygen)– containing molecules. Only the n–alkanes, and to a lesser extent, the isoprenoides of the saturate

Table 3.9: Results of CANOL oil spill residue analysis+ (sampled August 1978)

Characteristic / Site Number	Erect Deciduous Shrub Tundra				Plant Communities / Decumbent Deciduous Shrub Tundra							Sedge Meadow Tundra		Lichen Heath Tundra
	3	31	116	118	101A	101B	101C	112A	112B	115A	115B	105A	105B	104
Total Plant Cover (%)	0.9	5.0	0.0	0.0	78.5	0.1	20.0	45.0	0.2	27.0	78.0	0.6	22.0	0.3
Surface Organic														
Thickness (cm)	0-6	0-1	0-7	0-2	0-2	0-5	0-2	sand	0-3.5	0-8	0-3	0-6	0-3	0-1.5
Residual Oil (%)	5.6	6.9	18.6	16.0	11.6	18.3	7.1	and	60-80*	1.3	7.1	28.8	4.3	15.6
Decomposition	C	C	C	C	I	C	C	clay	S	C	I	I	I	I
1st Mineral Layer														
Thickness (cm)	6-8	Volcanic	7-26	2-6	2-5	5-20	2-6	12-13	3.5-21.5	8-10	5-10	6-8	3-6.5	0-3
Residual Oil (%)	0.6	Ash	1.4	13.4	4.6	0.2	0.9	56.0	1.4	0.1	0.4	8.8	5.4	0.9
Decomposition	I		I	C	P	C	?	S	P	?	C	?	I	P#
2nd Mineral Layer														
Thickness (cm)	Volcanic	10-15.5	26-38					13-14						3-5.5
Residual Oil (%)	Ash	0.9	0.9					11.8						5.1
Decomposition		S	S					P						I
3rd Mineral Layer														
Thickness (cm)	15-20		43-60											
Residual Oil (%)	0.1		0.3					clay						
Decomposition	I		S											
4th Mineral Layer														
Thickness (cm)								20.5-22.5						
Residual Oil (%)								1.7						
Decomposition								I						
Date of Spill●	2Oct44 or 16Aug44				16-17 Feb44	16-17 Feb44	16-17 Feb44	16Feb to Aug44	Aug44 to May45	16-17 Feb44	16-17 Feb44	26Feb44	26Feb44	26Feb44

+ analysis conducted by the Department of Microbiology, University of Alberta, following methods of Westlake and Cook 1980:15-21
* conta ns large amounts of silt which passed through the filter and consequently only a range could be determined
\# this was an organic surface layer, the first sample was from a dead moss polster
● sources include Public Archives Canada; Yukon Territorial Archives; Hemstock 1945; Tom Rimmer personal communication; National Air Photo Library 1944 Photography

'C' complete utilization of n-alkanes; 'I' only isoprenoides remaining; 'P' partial removal, n-alkane peak still discernible; 'S' selective metabo ism of n-alkanes C_{12} to C_{19}; '?' sample too small for analysis

fraction and the mono-, di-, and tri- ring compounds of the aromatic fractions are considered readily degradable by microorganisms (Westlake and Cook 1980). Unfortunately, which components cause plant damage and how, is not yet understood (Hutchinson et.al. 1976; Mackay et.al. 1979).

On a per cent by weight basis, the amount of oil remaining ranged from 0.1 to 60-80 % (Table 3.9). Spilled oil in Erect Deciduous Shrub Tundra had undergone complete decomposition of n-alkanes at the ground surface but less breakdown had occurred at depth. Spills in Decumbent Shrub Tundra had complete to selective decomposition of n-alkanes, and in one case only, the isoprenoides remained A decrease in level of degradation was found with increasing depth at several sites. A similar pattern was observed by Everett on the 28 yr old Fish Creek disturbances (Lawson et. al., 1978) and by Mackay and others in their studies of recent spills. In Sedge Meadow Tundra, only the isoprenoides remained. A spill in Lichen Heath Tundra still had isoprenoides at a depth of 5 cm in one surface sample and in another there had been only partial removal of n-alkanes. In the majority of cases, there was a noticeable drop in oil residue decomposition with increasing depth (Table 3.9). Much oil remains in the substrate after 34 years.

A relationship was found between the season of the oil spill and the present day plant cover (Table 3.9). Summer oil spills have maximum plant cover values of 5% whereas two winter spills now have 78 % cover. One implication of this is that some toxic substances may have been weathered out of the oil during the winter, before they could affect plant material capable of photosynthesizing. Wein and Bliss (1973) had the opposite occurring on 1 yr old winter oil spills and they postulated that the snow trapped the volatiles. The oil used in that study was the same crude that was transported by the CANOL Project.

Oil spill sites with the greatest degree of revegetation were found on moist substrates. The wet areas wouldn't have absorbed as much oil initially (Wein and Bliss, 1973). In addition the lower amount of oil in the substrate wouldn't penetrate as deeply as in dry areas (Table 3.9). As a result less of the rooting zone would have been contaminated on wet sites. Similar results have been noted by Walker and others (1978). Site 112 A had 45 % cover but the plants were rooted in 12 cm of sand and clay which

had been deposited over the spill, rather than in oil-soaked material. Where the oil has been buried, successful germination can occur. Otherwise, germination rates would be slow and seedling mortality high (McCown and Deneke 1972). Sites 105 A and 105 B differ in that 105 A is a relatively dry site located on top of a 40 cm high hummock (1.5 m in diameter) whereas 105 B was in the wetter, inter-hummock trough area. Plant cover was much higher on 105 B than on 105 A. Site 115 A is similar to 101 B and 115 B is similar to 101 A. However, the 115 A spill is on a much steeper slope than 101 B (i.e. 21^{0} versus 1^{0}) and has a higher perimeter to area ratio. On long, narrow spills, incoming plant disseminules have less distance to travel and some plants may invade via stolons or rhizomes from parent plants outside of the contaminated spill area. This may have been a factor contributing to the relatively high plant cover values on 115 A in comparison to 101 B.

3.4 Summary and Discussion

On a winter road (most comparable to the bladed trails of this study) that was in use the previous winter and a recent oil spill Haag (1973) determined that organic layers insulated the ground and retarded subsurface moisture loss. These observations were also confirmed by Babb and Bliss (1974) during the first season of track disturbances in the high arctic. In this study the removal of the organic surface layer also produced important differences between controls and several disturbances in all plant communities, with the exception of Cushion Plant and Crustose Lichen Tundra. On road, false start road, bladed trail, gravel pit and gravel pit access road disturbances the loss of organic matter most affected pH, moisture and subsurface temperatures. These characteristics control seed germination and survival success as is reflected by rooting depth and organic matter accumulations (on initially mineral-dominated substrates) 34-36 years after the initial disturbance. Some plant species prefer mineral surfaces for seed beds while others require organic sites. Unless the specific requirements of a given species are met, rates of germination success will be low. In control plant communities where organic matter is lacking or limited in the surface layers (e.g. Cushion Plant Tundra, Crustose Lichen Tundra) and on disturbances where surface layers have remained relatively intact (e.g. some bladed trails, bulldozer tracks) the differences between

controls and disturbances were relatively small.

A number of major points can be made, based upon the foregoing results and discussion. Substrate characteristics are part of a dynamic system and consequently many aspects are interrelated and cannot be considered in isolation. It is difficult to generalize with respect to the ecological consequences of substrate alterations resulting from CANOL disturbances. Ecologically, any substrate alteration can be important. A disturbance can produce conditions beyond the optimum or tolerance levels of many rooted plants or of most disseminals attempting to colonize it. In most cases, the responses of the plant community are determined by the ecological requirements of each species. For example, a disturbance that is wetter than its control may provide preferred habitat for one species while proving intolerable for another. For this reason, discussion in this chapter has been restricted to indicators of plant responses such as organic matter accumulations and rooting depth. Alterations may be sufficient to change conditions from an hostile to a more optimum substrate for plants.

Many surfaces were denuded of plants when they were disturbed. The current accumulations of organic matter on disturbances in several plant communities were a surprisingly high proportion of what was found on the associated controls. Accumulation of organic matter must be accelerating with time unless it has now stabilized. This implies that substrate conditions on some disturbances are not especially limiting to plant production in general. Substrate characteristics vary greatly among the 7 plant communities. For example, in Erect Deciduous Shrub Tundra, warmer subsurface temperatures may be promoting the rapid rate of organic accumulations. This is occurring in a plant community where moisture content of disturbed substrates is only a small fraction of that found in control sites. However, moisture content of disturbed substrates in Crustose Lichen Tundra was higher than that of the controls while subsurface temperatures were lower and organic matter accumulations were small and very similar to those found on control sites. In Crustose Lichen Tundra, moisture content appeared to be the limiting factor controlling organic matter accumulations on disturbances while in Erect Deciduous Shrub Tundra, subsurface temperatures seemed most important.

Several disturbances in all plant communities had substrates with different particle size composition than was found in their controls. The most significant difference was the greater gravel content found on several disturbances. As a result, the sand, silt and clay fraction was often only a small portion of the total volume. The absence of fine fractions, combined with the removal of surface organics on several disturbances increased through flow, decreased internal storage and increased the effectiveness of evaporation. All these conditions have been described for short–term disturbances (Haag and Bliss, 1974). Roads, false start roads, camp yards, gravel pits and gravel pit access roads were generally drier and warmer than controls (Table 3.10). Important exceptions to this occurred in Cushion Plant and Crustose Lichen Tundra where the controls lacked significant organic layers. Despite increased or unchanged gravel content, disturbance substrates here had more fine material and were able to retain more moisture. Consequently subsurface temperatures were generally cooler than in control areas.

Some bladed trails and most bulldozer track disturbances have left the surface organic layer intact and textural composition unchanged. Initial disturbances were minimal and these disturbed substrates were most similar to those of their controls. Exceptions occur where trails and tracks extend down slopes to trap and channel surface runoff. In some cases this resulted in rill erosion along the disturbance. These features became intermittent or even permanent water courses (Figure 1.2).

Another significant exception occurred predominantly in the Ekwi–Intga–Tsichu River Valleys and the Mackenzie Mountain Barrens Ecosections. The slight depression caused by tracks and trails trapped water and increased ground heat flux so that ice–rich permafrost thawed (Figure 1.2). The resulting thermokarst depression often contained standing water and certainly represents a much greater disturbance than that of the original CANOL disruption.

The preceding discussion of disturbances has been organized by plant community. A summary of the general characteristics of disturbed and undisturbed areas is presented in Table 3.10. Each type of disturbance can be placed on a continuum representing the degree of difference from control substrates.

Elevated disturbances generally had thinner snow cover and as a result were colder during the winter. In summer, they were warmer and more freely drained.

Table 3.10: A general summary of the relative differences in substrate characteristics between CANOL disturbances and undisturbed conditions, N.W.T.

Characteristics[1]	Road	False Start Road	Bladed Trail	Camp Yard	Bulldozer Track	Gravel Pit	Gravel Pit Access Road	Oil Spill
Atitude								
macro-relief	elevated and terraced 0-3 m	elevated, depressed & terraced 0-2 m	depressed 10-100cm	elevated 10-100 cm	in organics, 2 parallel ruts 5-25 cm deep	depressed 0.5-3 m	elevated and depressed 0.5-1 m	similar to control
micro-relief	level 5-10 cm	very irregular 20-100 cm	irregular 10-50 cm	level 0-15 cm	level 0-5 cm	irregular 10-75 cm	level to irregular 10-25 cm	similar to control
ditching	none to both sides	generally none	none	randomly located	none			
Compaction	extreme	slight to none	slight	extreme to none	none to moderate	slight to none	slight to moderate	slight
Surface Composition	mineral	mineral-organic	mineral-organic	mineral-organic	similar to control	mineral	mineral	oil saturated organics & tar residue
gravel content	high (75-100%)	none to high (0-100%)	none to high (0-75%)	little to high (20-100%)	similar to control	high (80-100%)	little to high (20-100%)	none
Predisturbance Soil	buried or removed	intact and patchy or removed	intact and patchy to removed	intact and patchy to removed	intact	removed	buried or removed to discontinuous	intact
Substrate Climate								
winter	colder, drier	colder-warmer, wetter-drier	warmer, moister-wetter	colder-warmer, moister-drier	warmer, moister	warmer, moister	cooler-warmer, moister-drier	similar to control
summer	warmer, drier	warmer, wetter-drier	cooler, moister-wetter	warmer, moister-drier	cooler, moister-wetter	warmer, wetter-drier	warmer, wetter-drier	warmer-hotter, drier
Drainage								
surface	unrestricted runoff	restricted runoff & retarded	collecting area	unrestricted runoff	collecting area	collecting area	unrestricted runoff-collecting area	similar to control
internal	freer	unimpeded-freer	unimpeded-freer	freer	similar to control	unimpeded-freer	unimpeded-freer	unimpeded

Table 3.10 continued

Characteristics[1]	Road	False Start Road	Bladed Trail	Camp Yard	Bulldozer Track	Gravel Pit	Gravel Pit Access Road	Oil Spill
Predisturbance Vegetation	eliminated	some changes-eliminated	partially-completely eliminated	discontinuous	similar to control-some changes	eliminated	partially-completely eliminated	eliminated
Timing of Disturbance	all seasons	all seasons	mainly fall & winter	all seasons	thaw season	all seasons	all seasons	all seasons
Post 1945 Disturbance	limited re-disturbance during salvage	some sections redisturbed	probably not redisturbed	limited re-disturbance during salvage	no redisturb-ance	no redisturb-ance	no redisturb-ance	some spills created dur-ing salvage
Other Remarks	road often submerged in areas of thermal erosion	most stretches never used, 1 section used in winter only	may channelize surface runoff & cause rill erosion	permafrost aggradation in the shade of some buildings	most resulted from 1 to few vehicle passes	a few used for road maintenance	often only an accumulation of fill lost from trucks	areas affected vary from few to 200 m^2

[1] These characteristics are relative to the undisturbed condition.

Depressed disturbances in organics were wetter and cooler in summer whereas mineral-dominated excavations were generally drier and warmer. On the wetter, eastern end of the study area, gravel pits often contained ponded water throughout the summer (Figure 1.2) whereas in the more arid, eastern section these features remained dry. Depressed sites had thicker snow cover in winter and as a result were warmer and moister than controls.

Substrates of different disturbances vary in their degree of compaction (Table 3.10). Compacted substrates act to increase surface runoff and therefore reduce water infiltration. In addition, root penetration is impeded. Consequently, a road offers a more hostile substrate environment for plants than does a false start road.

The season in which the disturbance was initiated has important implications for the degree and result of the initial impact. The CANOL disturbances provide examples from all seasons (Table 3.10). Specific disturbances were caused in only one season and some were not redisturbed during the salvage of the Project (Table 3.10).

3.5 Conclusion

Undisturbed soils in the study area were generally not well developed with thin surface organic layers (except Cryosols) and weakly developed mineral layers. This was the case despite the extreme age of sections of the study area lying within the unglaciated portion of the Mackenzie Mountains. Soils were generally cold and in areas with thick accumulations of organics, permafrost was often present. Regosols, Brunisols, Gleysols, and Cryosols were described from the region.

It is noteworthy that, with the exception of oil spills, there are numerous cases where disturbed substrates have responded positively after 34–36 years. Certainly, differences exist between controls and disturbances. However, it is difficult to equate or compare a substrate that is 34–36 years of age with a soil that is thousands or, in the unglaciated area, even a million years old. Even those substrates on such devastating disturbances as roads and gravel pits have accumulated organic matter and offer warmer substrates to colonizing plants in an environment where temperature is a major ecologically limiting factor. The removal or reduction of organic matter (primarily in the L–H horizon) and the lower fine particle content on many of the disturbances has created

drier conditions that can limit plant recolonization.

A significant point, with respect to CANOL disturbances is that no efforts were made to minimize the initial disturbance. The project proceeded with virtually no pre-planning, was executed without restrictions on construction and operation practices and no rehabilitation programme was instituted following its abandonment (Chapter 2). The substrate environment could certainly have benefited from positive measures in these areas. For example, in gravel pits, wall angles could have been reduced prior to abandonment and stockpiled topsoil then replaced, followed by mulching, fertilizing and seeding. Measures such as these would doubtless have resulted in much greater recovery than has been observed in the absence of rehabilitative efforts. The CANOL disturbances provide good examples of this. For example, false start roads where the pre-disturbance soil was removed had highly irregular surface topography, no drainage ditches, slight compaction and included some organic matter. These disturbances were frequently more similar to controls than were roads, which provided quite different substrates (Table 3.10). It is also likely that attempts to rehabilitate some types of disturbances (e.g. bulldozer tracks) might result in greater disruption than if left to recover naturally.

It is important to note that oil spill disturbances were severe and long-lasting. Data presented above indicate that, without rehabilitative measures, these disturbances will persist relatively unchanged for long period of time. For example, significant revegetation was occurring only on those sites where siltation had buried the toxic oily substrate or where wet or frozen soils had prevented the infiltration of large quantities of oil to depths greater than 8 cm (Table 3.9).

4. PLANT COMMUNITY ALTERATIONS RESULTING FROM CANOL DISTURBANCES

4.1 Introduction

The CANOL Project affected both forested and nonforested regions. Only alpine tundra, the area above timberline, was considered in this study (Figure 1.2). This chapter is concerned with the botanical characteristics of disturbances and comparisons of these sites with undisturbed tundra plant communities. Plant communities represent assemblages of plants that are reliant upon local physical and biological environmental characteristics for their maintenance. Even subtle environmental alterations can produce discernible plant community responses. The establishment of plants on human disturbances is a necessary step in rehabilitation. The biological productivity of these sites can be measured by the amount and health of their plant cover. Plants also provide food and/or cover for resident wildlife.

A number of objectives can be identified which relate to the botanical characteristics of CANOL Project disturbances. In pursuing the overall study objectives (Section 1.3), several more specific goals can be defined in reference to plant communities. One such objective was to determine the state achieved by disturbance plant communities, without human assistance, after 34–36 years. This included descriptions of how the disturbance plant communities differed from adjacent, undisturbed ones and this was evaluated by determining species cover differences, species richness and similarity coefficients. Another major objective was to determine which species were consistently successful at either revegetation of denuded surfaces or colonizing and/or increasing cover in areas of less severe modification. Additionally, it was deemed important to include those species that were significantly reduced in cover on disturbances when compared to controls. The latter group of plants was detrimentally affected by disturbances or poorly adapted to colonization of disturbances. Lists of species displaying significant cover differences from controls were compiled to meet this objective.

A third objective was to determine how disturbances affected the site's plant productivity. This was impossible without detailed, time consuming studies. However, within constraints it can be indirectly evaluated by determining the above-ground

phytomass on disturbances and comparing the result with that of adjacent, undisturbed areas.

Another objective was to determine the rapidity of recovery by woody plants. Ages of shrubs found on disturbances were used to determine the minimum date of colonization. These data provided mean colonization dates and therefore an indication of the time period over which successful recovery had proceeded.

4.2 Methods

4.2.1 Pre-Fieldwork Methods

Detailed aerial photographic interpretation was completed using trimetrogon 1943 (1:34,500 scale), trimetrogon 1944 (1:24,760 scale) and vertical 1974 (1:40,000 and 1:12,000 scale) diapositive, black and white, 230 mm x 230 mm photography. Paper field copies were enlarged from selected portions of these to be used for making notations during the field sampling. Reference was made to additional aerial photography in the National Air Photographic Library and the Public Archives of Canada in Ottawa and through the United States Defense Intelligence Agency, Washington. These collections have various dates and are at a variety of scales.

The choice of areas for field investigation was based mainly on the initial aerial photographic interpretation. Three main considerations governed the choice of study sites.

1. Each site had to be representative of the conditions found in that area.
2. Sites with the largest number of disturbance types were selected in an effort to maximize the amount of information gained.
3. Disturbances had to be a short distance from one another and close to a suitable, undisturbed area that could be used as a control site.

When the literature review and photogrammetric work had been completed, a checksheet of items to be investigated during fieldwork was compiled to be carried with the appropriate topographic maps (1:250,000 scale with a 152 m or 500 ft. contour interval), aerial photographic enlargements (1944 images at 1:8,000 scale and 1974 images at 1:3,050 scale plus diazo prints from the 1974 diapositives at 1:40,000 scale),

field books, and standardized sampling forms. The check sheet helped to provide a systematic analysis at each sample point ensuring that resulting data would be comparable between sites.

4.2.2 Field Methods

Fieldwork was conducted from 15 June to 29 August in 1977, from 13 July to 3 October in 1978 and from 23 June to 27 August in 1979. Vascular and non-vascular (bryophytes and lichens) plant specimens were collected at each sample site. Detailed investigations were conducted during the spring, summer and fall seasons with random observations during the winter months regarding such factors as exposure and wildlife utilization.

Most sampling locations were selected prior to fieldwork on the basis of aerial photographic analysis. However, the ground reconnaissance survey completed during the summer of 1977 was also considered when selecting sites for study in 1978 and 1979. Localities encompassing one to eight different types of disturbance within areas of uniform plant community, micro- or meso-topography and soil characteristics were selected. Adjacent, undisturbed plant communities were used as an indicator of site homogeneity prior to disturbance. Actual sites (disturbances and controls) to be sampled were selected as representative of the area following a general survey to determine the extent of local variations in plant communities. Where dramatic changes in plant communities occurred within one disturbance type, samples were taken from each type and treated separately. The distance between sampling sites was kept to a minimum in an effort to reduce potential errors arising from local variations in topography, substrate and plant communities.

Aerial photo enlargements were used in conjunction with detailed field examinations to select control sites. Areas showing evidence of disturbance (e.g. abrupt changes in plant cover or species composition etc.) or appearing to have been influenced by adjacent disturbances were rejected. In addition, controls were selected from sites above the disturbed area. This was relatively straightforward on shrub- or lichen-dominated sites where most disturbances had resulted in plant community structure alterations. On dry substrates with sparse plant cover, it was usually possible to

discern areas where compaction had resulted from vehicular activity.

Five, contiguous, 0.5 x 1 m quadrats were used for sampling vegetation in areas dominated by erect shrub communities. In other communities, 5 contiguous, 0.5 x 0.5 m quadrats were sampled. For each quadrat, plant cover was estimated for each species [10]. using a modified Braun-Blanchet cover classification and verbal descriptions of physiognomy, structure and vigour were made. Lichens were the only common epiphytes and were found at all levels on the bark of shrubs. Terrestrial algae and the fruiting bodies of fungi were also noted when present. Non-plant material was classified as mineral, organic or anthropogenic and cover was recorded for each category.

Prior to sampling, the quadrats were photographed in black and white and in colour, showing a range pole in the upper right and a sign identifying the quadrat by number, mile post location, disturbance type, and date of sampling. Two pegs were then marked with blue flagging tape and placed in the lower left and upper right corners of the quadrat. Plants from similar, adjacent areas but not noted in the quadrat were also collected and/or noted as present.

Observations were made in areas that were not sampled in a systematic fashion. These included the collection of rare plants not found in sampled areas and the measuring of unusually tall shrubs. A wide variety of methods was used to collect data in special cases and individual examples will be outlined when related observations are discussed.

Above-ground phytomass (live standing crop) was collected from representative sites. At each site, three 0.17 m^2 quadrats, each measuring 33.3 cm by 50 cm, were denuded and the total plant material weighed to the nearest gram. Subsamples were then retained for later drying. When samples were large and contained a high proportion of woody material, the herbaceous components (including lichens, mosses and non-woody vascular plants) and woody species were weighed seperately and one subsample of each was taken. Samples and subsamples including both woody and herbaceous species were classified as 'undifferentiated'.

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[10]Due to taxonomic difficulties with many of the non-vascular plant taxa, it was often necessary to refer to plants by genus (e.g.*Cladonia* sp.; *Polytrichum* sp.) or by broader groups (e.g. crustose lichens; moss spp.). Through plant collections, it was later possible to compile relatively complete species lists for each site. However, per cent cover estimates for each taxon could not always be calculated as each of these categories could include several species. Cover by vascular plants was recorded for each species present.

On disturbed sites with shrubs, a root crown was taken for aging. The largest specimen(s) was sampled since that was presumably the oldest and certainly the most robust shrub at that site.

4.2.3 Post-Fieldwork Methods

4.2.3.1 Specimen Treatment

Voucher collections were identified by L.J. Kershaw (vascular plants), C. LaFarge–England (bryophytes) and J. Marsh (lichens). Vascular plant identifications were verified by W.J. Cody and G.A. Mulligan at the Vascular Plant Herbarium, Biosystematics Research Institute, Canada Department of Agriculture (DAO) and by G.W. Argus at the National Herbarium of Canada, National Museums of Canada (CAN). Vascular plant collections were placed in both CAN and DAO and one was retained in the Department of Geography, University of Alberta. Unless otherwise stated, nomenclature follows that of Porsild and Cody (1980) and Argus (1973) for vascular plants; that of Crum, Steere and Anderson (1973), Hale and Culberson (1970) and Steere (1978) for bryophytes; and that of Thomson (1967, 1979) for lichens.

Phytomass subsamples were oven–dried at 70°C for 24 hours and then allowed to cool to room temperature before being weighed to the nearest 0.1 g (Kalra 1971:52). Oven dry weight was expressed as a fraction of the subsample green weight and multiplied by the total sample weight to determine the standing crop in g/m^2 from each site.

Shrub ages were determined using ring counts on root crowns. Specimens were prepared in one of two ways. Large root crowns were cross–sectioned and fine–sanded before counts were made with the aid of a dissecting microscope. Smaller specimens were sectioned, impregnated with glycerine, thin–sectioned, stained and then viewed using a compound microscope. In all cases, root sections were used.

4.2.3.2 Computer Analysis

Several phases were involved in the analysis of the vegetation data. These included standard arithmetic and statistical treatments of the above–ground phytomass and shrub age data; derivation of species cover means in each stand (Honsaker 1981);

and the application of COMPCLUS (Gauch 1979) to the quadrat data.

The cover values from each of the five contiguous quadrats were averaged for each plant or plant group and these data were then made available for the COMPCLUS program. COMPCLUS is a computer programme which identifies stands on the basis of species composition and cover similarities. The clusters identified represent plant communities. With analysis of control sites, a 'percentage distance' (Gauch 1979) radius of 82.66 was used with no data transformations. The results emphasize the dominant components for each site based upon per cent cover values.

The number of species present at each site and those held in common with the control were noted and the results of this species richness analysis were then subjected to Sorensen's treatment in order to develop an Index of Similarity (Mueller-Dombois and Ellenberg 1974) comparing the plant communities of the disturbances with that of their controls. The following equation was used for these calculations:

$IS = 2C \times 100 / A+B$

In this treatment, 'A' represents the total number of species on the disturbance, 'B' the total number of species on the control, and 'C' the number of species common to both. Two identical floras would have a similarity coefficient of 100 whereas a value of 0 would result when the two sites had no species in common.

The mean cover value for each species or plant group at a site was compared with that of its control by subtracting the average cover in the control from the average value recorded in an associated disturbance.

$CC = [\ (D_1-C_1) + (D_2-C_2) \ldots + (D_n-C_n)\ ] / n$

D_1 is the mean cover of the samples of a species in the 5 quadrats on a disturbance at site one

C_1 is the mean cover of the samples of a species in the 5 quadrats in the adjacent control stand

D and C are the mean cover values for the same species at site 'n'

n is the number of sites sampled

This produced control-corrected (CC) data for all disturbances at each sample location. Mean differences from controls were then compiled by deriving the average of all of the relevant control-corrected values for that species. A positive value indicated an increase

in cover and a negative value reflected a decrease for that species. When a species was not present in a disturbance, it was recorded as 'occurring in controls but not in disturbances'. A species or cover category may be found on both lists if it was missing from a disturbance while present on the associated control in one case but present on the disturbance at another site.

4.3 Results and Discussion

A total of 311 stands (i.e. 1,555 samples) were sampled to determine their botanical characteristics (Table 4.1). One hundred and seventy-two root crowns from 144 sites (63% of the disturbed stands) were examined to establish their age (Table 4.1). Above-ground phytomass was measured at 138 sites (414 quadrats denuded) or 45% of the plant community sampling sites (Table 4.1). In all, 169 lichen, 115 bryophyte and 303 vascular plant taxa were collected - a total of 587 plant taxa (Appendix IV).

4.3.1 Plant Community Alterations

Seven major physiognomically defined plant communities were identified within the study area. Their definition was based primarily on structure and consequently there is often more than one floristically defined plant community in each. For example, areas of Decumbent Shrub Tundra could be dominated by several species including *Salix reticulata, S. arctica* and *Dryas integrifolia*. Conversely, plant communities dominated by *Betula glandulosa* could fall within the category of Erect Deciduous Shrub Tundra when plants were robust or within Decumbent Shrub Tundra when adverse conditions resulted in shrubs of reduced size. Each floristic community will be discussed within the structural plant community that best typifies it. This was done to ensure that the detail of species composition would not be obscured by comparisons including the several floristically dissimilar plant communities that have been lumped into one physiognomically defined plant community. These data will be more useful to botanists and biogeographers in this format since it permits comparisons with similar plant communities described from elsewhere. Furthermore, using species composition data, species showing promise for revegetation programmes and those that are especially sensitive to disturbance or poorly adapted to successfully respond to environmental change can be identified.

Table 4.1: Summary of botanical sampling of control sites and CANOL Project disturbances, N.W.T.

Sample Type	Control	Road	False Start Road	Bladed Trail	Camp Yard	Bull-dozer Track	Gravel Pit	Gravel Pit Access Road	Oil Spill	Total
# of Quadrats Sampled	89	54	7	40	1	19	58	16	27	311
# of Root Crowns Sampled	5	51	7	35	1	9	47	11	5	172
# of Phytomass Samples Taken	34	30	3	17	1	10	25	8	10	138

The COMPCLUS analysis served to identify 15 plant communities from the 89 control stands. The plant community titles include the plants with the highest mean cover values in that cluster.

Only species with mean disturbance cover values at least 2% greater or less than those recorded on the control sites will be discussed in the following sections. However, some inclusive categories such as miscellaneous lichens and mosses may include species with cover differences of less than 2%. These species and plant groups showed a broad spectrum of alteration ranging from local extinction to introduction into new areas on the disturbance, as a dominant component of the plant community. A list of the cover differences between disturbances and controls for all taxa is presented in Appendix VI.

The many rare plants in the various communities are not discussed on an individual basis. A plant with less than 2% may be rare because it requires special microhabitat characteristics in order to survive or it may have limited reproductive capability. These plants may prove most sensitive to disturbances and as such could be significant indicators of change. However, to use them in this way requires a detailed understanding of the autecology of each species and few such studies exist. However, rare plants are considered when discussing species richness and similarity coefficients at a site and have been included in the species lists showing cover value differences (Appendix VI).

Species richness is equivalent to the number of plant taxa in the control or disturbance stand. When determining species richness even those taxa only occurring once in several samples, were included in the total.

4.3.1.1 Erect Deciduous Shrub Tundra

Erect Deciduous Shrub Tundra includes those plant communities with a shrub layer over 30 cm tall covering at least 50% of the area under plants. In the study area, such communities were dominated by *Salix* species and *Betula glandulosa*. Variation in floristic composition occurred, with a number of distinct, floristically defined plant communities present. These included *Hedysarum alpinum*–Moss, *Salix reticulata-Salix lanata*-Moss and *Betula glandulosa-Cladonia stellaris*-Moss communities.

These plant communities were abundant in the Joker Ridge and Bolstead Creek–Devil's Pass Ecosections. Detailed descriptions of these ecosections are presented in Section 1.6. Generally, Erect Deciduous Shrub Tundra dominated lower

elevations on imperfectly– to well–drained soils (Section 3.3.1).

Hedysarum alpinum - Moss Community

This plant community can be classified as riparian since it dominates on flood plains where annual flooding occurs. Robust *Salix alaxensis* generally exceed 1.5 m in height and commonly reach 4 m. The understory is dominated by *Hedysarum alpinum*, mosses such as *Campylium stellatum*, *Bryum bimum*, *Distichium inclinatum*, *Drepanocladus sendtneri*, *D. uncinatus*, *Hypnum lindbergii* and *Tomenthypnum nitens* as well as the prostrate *Salix reticulata* (Table 4.2).

Three control stands were sampled and all were located in the Intga River Valley between R.M.P. 194.3 and R.M.P. 200.8 (Figure 1.3). Road, bladed trail, bulldozer track, gravel pit and gravel pit access road disturbances were sampled here.

Hedysarum alpinum had less cover on all disturbances than in controls (Appendix VI, C). *Salix alaxensis*, which commonly comprises a high percentage of the cover on disturbances, had less cover on controls than on all disturbances with the exception of the road (Table 4.3). Moss cover was less on the road, bladed trail and bulldozer tracks but greater on the gravel pit and gravel pit access road sites than in the adjacent undisturbed areas. Species composition differences (Appendix VI, C) and substrate variations among these disturbances have probably caused these differences. This was not the result of variation in any one factor but rather of several different components important at each site.

Similarity coefficients indicate that the road flora is most like that of the control, while the gravel pit plant community was least similar (Table 4.4). Species richness values indicate that the number of species was greater than that of the controls in gravel pits only (Table 4.5). .

The overall decline in species richness and low floristic similarity to control plant communities may indicate that environmental conditions were more restrictive for plants on disturbances than in undisturbed areas. Furthermore, the 'new' disturbance environments were not suitable for local

Table 4.2: Average cover values for the undisturbed *Hedysarum alpinum*-Moss Plant Community (n=3)

Species	Cover	n	Species	Cover	n	Species	Cover	n
BET GLAN	0.01	3	ARN LESS	0.01	3	AST SIBI	0.75	3
ERI ERIO	0.01	3	SEN LUGE	0.01	3	SOL MULT	0.01	3
CAR AURE	0.01	3	CAR CAPI	0.09	3	CAR MEMB	0.01	3
CAR SCIR	0.01	3	ERI CALL	0.01	3	SHE CANA	0.04	3
EQU ARVE	0.04	3	EQU VARI	0.25	3	ARC ALPI	0.19	3
GEN PROP	0.25	3	AGP VIOL	0.01	3	ARC LATI	0.04	3
DES CAES	0.01	3	FES ALTA	0.01	3	POA ALPN	0.01	3
TRS SPIC	0.01	3	JUN CAST	0.01	3	JUN ALBE	0.01	3
HED ALPI	34.50	3	OXY DEFL	0.09	3	TOF PUSI	0.04	3
ZYG ELEG	0.01	3	EPI ANGU	0.01	3	EPI LATI	0.01	3
POL VIVI	0.54	3	ANE PARV	0.19	3	SAL ALAX	6.07	3
SAL LANA	0.90	3	SAL RETI	9.51	3	PAR KOTZ	0.01	3
PAR PALU	0.01	3	PEDIC SP	0.04	3	FUNGI	0.29	3
BASIDIOM	0.04	3	HEPATICS	0.0	3	MOSS SPP	24.00	3
BRY BIMU	0.0	1	CAM STEL	0.0	1	DIS INCL	0.0	1
DRE SEND	0.0	1	DRE UNCI	0.0	1	HYP LIND	0.0	3
TOM NITE	0.0	3						

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

Table 4.3: Plants with significant cover value differences (2%) between control and CANOL Project disturbance plant communities, N.W.T.

Plant Species or Group	Erect Deciduous Shrub Tundra			Decumbent Shrub Tundra			Sedge Meadow Tundra			Lichen Heath Tundra	Fruticose Lichen Tundra	Cushion Plant Tundra			Crustose Lichen Tundra
	Hedysarum alpinum-Moss	*Salix reticulata*-*Salix lanata*	*Betula glandulosa*-*Cladonia stellaria*-Moss	*Salix barrattiana*-Moss	*Salix polaris*-*Dactylina beringica*	*Dryas integrifolia*-*Carex* spp.	*Carex membranacea*-*Sphagnum* spp.	Misc. Mosses-*Carex* spp.	*Carex* spp.-*Kobresia simpliciuscula*	*Dryas integrifolia*-*Cassiope tetragona*	*Cladonia stellaris*-*Alectoria ochroleuca*	*Dryas integrifolia*-*Cetraria tilesii*	*Dryas integrifolia*-*Rhizocarpon umbilicatum*	Saxicolous Lichens-*Lecanora epibyron*	*Rhizocarpon inarense*-*Umbilicaria proboscidea*
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LICHENS															
Rinodina roscida															
Cladonia arbuscula			-RP									+O			
C. coccifera			-A												
C. crispata								-RB							
C. gracilis			-A												
C. macrophylla			-B					+T			-FP				
C. mitis			-RBC TPO								-FP				
C. pocillum		+O													
C. pyxidata		+O													
C. rangiferina			-BC PAO					-RB TPA			-RB PAO				
C. stellaris			-RBT PAO					-RB TPA			-RFB TPAO				
S. subulata								+T							
Collema sp.			+P												
Lecanora epibyron												+P			
Lecidella stigmatea												-RP	-BP	-RBP	
Rhizocarpon sp.											+A				+B
R. eupetraeoides											-FBT PAR				-RF BP
R. inarense															+B
R. umbilicatum															-RB
Toninia lobulata			+P										-RBP		
Pannaria pezizoides			+P								+P	-RBP			
Psoroma hypnorum			+P												
Asahinea chrysantha											-FBP				
Cetraria cucullata						-RBT PAO		-O		-RB PO	-RP AO	-T			
C. islandica			-RB +A			-TAO				-RP AO	-RFB PAO				

Table 4.3 continued

	Erect Deciduous Shrub Tundra			Decumbent Shrub Tundra			Sedge Meadow Tundra			Lichen Heath Tundra	Fruticose Lichen Tundra	Cushion Plant Tundra			Crustose Lichen Tundra
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cetraria laevigata											-RFBP				
C. nivalis			-BT PA							-FP	-RFB TPAO				
C. tilesii										-FP		-RTB PAO			
Peltigera aphthosa			+C								+RT				
P. canina			+B					+B							
P. polydactyla											+R				
P. pulverulenta					+T										
P. rufescens		+R	+B												
Solarina crocea			+A												
Stereocaulon alpinum			+R					+BP							
S. pachale			-RBT PAO					-A							
S. saxatile			+B					+B							
S. tomentosum								+RBP							
Umbilicaria hyperborea															-RB
U. proboscidea															-RB
Alectoria ochroleuca										-RB PAO	-RFB TPAO	-BT AO			
Dactylina beringica								-PA							
Thamnolia subuliformis										-FP					
Polyblastia sendtneri													-BP		
Thelidium aenovinosum												+B			
Miscellaneous Lichens		+0	+0	+0		-RBP		+RBP		+0					
Crustose Lichens			+B							+B	-RB PO	-RF BP			
Saxicolous Lichens											-RFB TPA	-RF +BT PO		-RBP	-RF +BP
Soil Lichens			+BP					+BP	+P	+0 -RF BP	+BP +RF BA	+BA -RFP	+BP -RP	+P -RP	
MOSSES															
Aulacomnium palustre			-PO												
A. turgidum			-B												
Polytrichum spp.			+P					+B			+BPA				+R
P. commune			-BTPO +A												+P
P. hyperboreum											+B				
P. juniperinum			-BPA								-F +RP				
P. piliferum			+BPA								+R				
P. strictum			+T												+P
Sphagnum spp.							-0								
Miscellaneous Mosses	-RBT +PA	-R PO	-RP +BTO	-B +R TO	+R TA		-0	-RB TP		-RBT PAO	+FT	+AO	-BTP		-P +R

Table 4.3 continued

	Erect Deciduous Shrub Tundra			Decumbent Shrub Tundra			Sedge Meadow Tundra			Lichen Heath Tundra	Fruticose Lichen Tundra	Cushion Plant Tundra			Crustose Lichen Tundra
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
VASCULAR PLANTS															
Betula glandulosa			-RBC TPAO							-F	-RF PAO +BT	-RTB PAO			
Mertensia paniculata				-RB TPO											
Linnaea borealis											+B				
Minuartia arctica											+R				
M. macrocarpa											+RFA				
M. rossii									+R						
M. rubella															+R
Silene acaulis										-FP		-RFT PAO			
Antennaria densifolia										+B					
A. stolonifera			+A												
Artemisia arctica			-RPT					+R							
A. tilesii								+R							
Chrysanthemum integrifolium										+F					
Petasites hyperboreus								+P							
Solidago multiradiata		+0													
Carex aquatilis aquatilis				+B						+0					
C. aquatilis stans			+RB					-RBT							
C. atrosquama			+P												
C. capillaris			+B												
C. lugens															+F
C. membranacea	+T		+BP	+T		+B	-0		-RP	+0B		+RO			
C. microchaeta								+B			+B				+P
C. misandra						-R				-P					
C. petricosa										-RB PAO		-RB PAO +T		-RBP	+R
C. podocarpa								-RTP +B	-RP	-RBP	+BP				
C. rupestris						-R PA				-RFB PAO		-RBT PAO		-BP	
C. scirpoidea		+0				+B				-RF PO	+B	-RBT PAO	-R	-RBP	
Eriophorum angustifolium							+0	+BP	-RP	-RPA +B			-P		
E. vaginatum							-0								
Kobresia simpliciuscula						-RP			-R				+P		
Shepherdia canadensis						+R									
Empetrum nigrum			-R +C								+A				
Equisetum arvense	+BT		+R	-RB TPO				+R							
E. variegatum	+P		+P												

Table 4.3 continued

	Erect Deciduous Shrub Tundra			Decumbent Shrub Tundra			Sedge Meadow Tundra			Lichen Heath Tundra	Fruticose Lichen Tundra	Cushion Plant Tundra			Crustose Lichen Tundra
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Andromeda polifolia							-0								
Arctostaphylos alpina			-R	+R		-RBP				-FP	-A				
A. uva-ursi			-RP												
Cassiope tetragona								-RB TPA		-RF BTP	-RB PO				
Ledum decumbens											+AT				
L. groenlandicum			-R												
Rhododendron lapponicum										-PA					
Vaccinium uliginosum			-R							-RBP	+T		-RTB		
V. vitis-idaea											-F +BT				
Arctagrostis latifolia				-BT PO				-RTP +B							
Calamagrostis canadensis			-TPO												
Deschampsia caespitosa			+RB	+B	+TA			-RT							
Festuca altaica			-P					-RB TPA			-P				
		+0	+RB CA								+F				
Hierochloe alpina											-PA +F				
Poa alpina				+0				+B							
P. arctica					+R			+R							
P. glauca											+R				
P. porsildii								-PA							
P. pratensis								+R							
Trisetum spicatum				+0	+RTA			+RBP							
Juncus albescens												+0			
J. balticus			+R												
J. castaneus															
Luzula arcuata								+B							
L. confusa											+F				
L. parviflora					+T										
Hedysarum alpinum		-RB PO										+F			
H. mackenzii		+R													
Epilobium anagallidifolium								+R							
E. angustifolium			+C	+BO											
E. latifolium				+T				+A			+P				
Polemonium acutifolium				-RB TPO											
Androsace chamaejasme												+T			
Aconitum delphinifolium				-RB TPO											
Anemone narcissiflora								-A							
A. parviflora								-B							
Thalictrum alpinum				-RB TPO											

Table 4.3 continued

	Erect Deciduous Shrub Tundra			Decumbent Shrub Tundra			Sedge Meadow Tundra			Lichen Heath Tundra	Fruticose Lichen Tundra	Cushion Plant Tundra			Crustose Lichen Tundra
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dryas integrifolia	+A		+P			-RB PA			+P	-RFB TPAO		-RB PAO +FT	-RBT PAO	-RP	
D. octopetala											-FB PA				
D. sylvatica											-FP	+A			
Geum rossii								-BPA							
Potentilla biflora										-RB PAO					
P. fruticosa						+R									
Sibbaldia procumbens					+T			+P							
Salix alaxensis	-BTP +R	+R BP	+RB						+RP	+RF BPA	-A +RP	+RF PA	+RA	+R	
S. arbusculoides															+F
S. arctica					+T			-T		-O			+T		
S. barrattiana				-RB TPO							-FP				
S. commutata								-RBP							
S. glauca		+RP		+R							+F				
S. lanata		-RB PO						+P							
S. planifolia			-TP +AO		+T	+B		-RPA +P			-A +RB				
S. polaris					-RT PA			-PA							
S. reticulata	-RB PA +T	-RB PO	-FP	+RTP					+P		-A	-BT			
Saxifraga oppositifolia						-B				+A					
Pedicularis capitata											-B				
P. lanata						-BP									

'+': cover values at least 2% higher on the disturbances than in the control plant community
'-': cover values at least 2% lower on the disturbance than in the control plant community
'R': road; 'F': false start road; 'B': bladed trail; 'C': camp yard; 'T': bulldozer track
'P': gravel pit; 'A': gravel pit access road; 'O': oil spill plant communities

Table 4.4: Floristic similarity coefficients comparing control plant communities with those of CANOL Project disturbances, N.W.T.

Plant Communities	Road	False Start Road	Bladed Trail	Camp Yard	Bulldozer Track	Gravel Pit	Gravel Pit Access Road	Oil Spill	$\bar{x}$
	Disturbance Type								
Erect Deciduous Shrub Tundra									
Hedysarum alpinum-Moss spp.	58		53		44	38	54		49
Salix reticulata-*Salix lanata*	56		39			18		30	36
Betula glandulosa-*Cladonia stellaris*-Moss spp.	33		51	30	75	51	44	48	47
Decumbent Shrub Tundra									
Salix barrattiana-Moss spp.	23		33		54	24		24	32
Salix polaris-*Dactylina beringica*	23				48	40	28		35
Dryas integrifolia-*Carex* spp.	54		46			61	42		51
Sedge Meadow Tundra									
Carex membranacea-*Sphagnum* spp.								19	19
Miscellaneous Mosses-*Carex* spp.	42		49		74	47	42		51
Carex spp.-*Kobresia simpliciuscula*	33					54			44
Lichen Heath Tundra									
Dryas integrifolia-*Cassiope tetragona*	50	47	63			53	42	52	51
Fruticose Lichen Tundra									
Cladonia stellaris-*Alectoria ochroleuca*	38	52	48		39	52	57	22	44
Cushion Plant Tundra									
Dryas integrifolia-*Cetraria tilesii*	53	46	66		52	58	44	52	53
Dryas integrifolia-*Rhizocarpon umbilicatum*	54		58		52	50	58	21	49
Saxicollous Lichens-*Lecanora epibyron*	50		54			55			53
Crustose Lichen Tundra									
Rhizocarpon inarense-*Umbilicaria proboscidea*	06	00	25			00			08
Mean Similarity Coefficient (all communities)	41	36	49	30	55	42	44	34	41

'$\bar{x}$': mean similarity coefficient for all types of disturbances in that community

Table 4.5: Plant species richness of control and CANOL Project disturbance plant communities, N.W.T.

Plant Communities	Road			False Start Road			Bladed Trail			Camp Yard			Bulldozer Track			Gravel Pit			Gravel Pit access Road			Oil Spill		
	D	C	S	D	C	S	D	C	S	D	C	S	D	C	S	D	C	S	D	C	S	D	C	S
Erect Deciduous Shrub Tundra																								
Hedysarum alpinum-Moss spp.	6	25	21				21	22	24				15	25	16	47	24	22	18	22	24			
Salix reticulata-*Salix lanata*	11	6	11				29	6	11							23	13	4				20	11	6
Betula glandulosa-*Cladonia stellaris*-Moss spp.	49	54	25				90	22	59	33	13	10	27	13	59	120	30	78	28	18	18	29	33	28
Decumbent Shrub Tundra																								
Salix barrattiana-Moss spp.	21	33	8				48	26	18				25	20	26	58	32	14				19	37	9
Salix polaris-*Dactylina beringica*	21	27	7										33	13	21	22	20	14	9	27	7			
Dryas integrifolia-*Carex* spp.	15	38	31				13	18	13							15	32	37	3	25	10			
Sedge Meadow Tundra																								
Carex membranacea-*Sphagnum* spp.																						4	22	3
Miscellaneous Mosses-*Carex* spp.	64	61	45				62	29	43				27	30	83	61	56	51	19	47	24			
Carex spp.-*Kobresia simpliciuscula*	9	20	7													16	11	16						
Lichen Heath Tundra																								
Dryas integrifolia-*Cassiope tetragona*	49	85	66	25	44	31	34	54	75							37	81	67	25	52	28	20	56	41
Fruticose Lichen Tundra																								
Cladonia stellaris-*Alectoria ochroleuca*	95	28	38	56	36	49	71	17	40				18	13	10	62	47	59	20	15	23	7	29	5
Cushion Plant Tundra																								
Dryas integrifolia-*Cetraria tilesii*	41	50	52	19	30	21	14	35	47				16	32	26	32	46	53	19	36	22	14	33	25
Dryas integrifolia-*Rhizocarpon umbilicatum*	11	46	33				30	45	52				12	30	23	31	42	37	8	17	17	7	30	5
Saxicolous Lichens-*Lecanora epibyron*	11	36	23				1	26	16							9	28	23						
Crustose Lichen Tundra																								
Rhizocarpon inarense-*Umbilicaria proboscidea*	73	22	3	39	16	0	28	13	7							30	16	0						

'D': no. of species found in disturbed plant communities only
'C': no. of species found in control plant communities only
'S': no. of species common to both control and disturbance plant communities

species. Alternatively, 34–36 years may not be a sufficient length of time for natural recovery to establish new plant communities. Further colonization and cover changes may yet occur. However, in comparison with other disturbance plant communities, those studied here have been slow in their recovery. A significant difference between the tall shrub control plant communities and those containing only one synusia reflected the effects of shrub removal. The moderating effects of the shrub canopy were eliminated or at least reduced for a number of years following the initial disturbance. Similar results were noted by Gill (1973) with the removal of tree and shrub canopies in the Mackenzie Delta region. In most cases, the present disturbance shrub canopy still remains open. Local plant species would be well adapted to the protected, shaded environment below a continuous shrub canopy, and as is reflected by the low similarity coefficients, its removal has precluded colonization by these species. Until the closed canopy is replaced (probably by the shrub species currently on the disturbed sites), the disturbances will continue to be substantially different from control plant communities.

Salix reticulata - Salix lanata - Moss Community

This plant community was dominant in seepage areas and sites where soils were moist. *Salix lanata* formed a 1.5 m tall overstory but the ground cover was similar to that of the *Hedysarum alpinum*-Moss plant community (Table 4.6) with some differences in the ranking of dominants.

Three control stands were sampled, all located in the Intga River valley between R.M.P. 200.6 and R.M.P. 203.8 (Figure 1.3). Disturbances included road, bladed trail, gravel pit and oil spill sites.

Salix lanata, S. reticulata and *Hedysarum alpinum* had less cover than controls on all disturbance types than in the control plant community (Appendix VI, F and Table 4.3). Cover values for *Salix reticulata* were 57% lower than controls on the roads in this plant community. However, *Salix lanata* was restricted to undisturbed areas. With the exception of oil spill sites, *Salix alaxensis* had greater cover on disturbances than in control stands.

Table 4.6: Average cover values for the undisturbed *Salix reticulata*-*S. lanata* Plant Community (n=3)

Species	Cover	n	Species	Cover	n	Species	Cover	n
AST SIBI	0.04	3	CAR MEMB	0.14	3	CAR SCIR	0.14	3
EQU VARI	0.75	3	ARC LATI	0.09	3	HED ALPI	2.12	3
OXY DEFL	0.09	3	EPI LATI	0.04	3	POL VIVI	0.25	3
ANE PARV	0.19	3	POT FRUT	0.01	3	SAL ALAX	0.01	3
SAL BARR	0.01	3	SAL LANA	10.30	3	SAL MYRT	0.01	3
SAL RETI	58.00	3	PAR KOTZ	0.04	3	MOSS SPP	6.95	3

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

All disturbance plant communities had greater species richness than did their associated controls (Table 4.5). However, on the basis of similarity coefficients species composition of the road was most similar to that of the controls, while that of the gravel pit was least similar to the undisturbed flora (Table 4.4).

Disturbances must provide radically different environmental conditions when they occur in this community, with the result that they provided habitat for a greater number of species. However, it appears to be unsuitable for local species since the flora on disturbances was very different from that of the controls.

Betula glandulosa - Cladonia stellaris - Moss Community

In terms of the entire study area, this plant community occupied one of the greatest areas. It was found throughout the study area but most commonly at lower elevations in the western section. Whereas the other plant communities in Erect Deciduous Shrub Tundra were confined to floodplains and seepage areas, the *Betula*–dominated systems covered large areas in an almost unbroken cover. *Betula glandulosa-Cladonia stellaris*–Moss plant communities mantled the areas of till, near–surface bedrock, alluvium and lacustrine deposits. These sites could be imperfectly to well–drained. Shrub stature varied considerably from the extremely dense stands which exceed 2 m in height to those that would most properly be classified as prostrate. Differences in heights are due primarily to exposure and mean snow depth. In the category 'Gramineae species' (Table 4.7), *Deschampsia caespitosa, Trisetum spicatum* and *Festuca altaica* had equal cover. The most common moss species included: *Hylocomnium splendens, Polytrichum juniperinum, P. piliferum* and *P. strictum* .

Fourteen control stands were sampled in the following areas: (1) R.M.P. 187.7 to R.M.P. 189.8, (2) R.M.P. 204.0 to R.M.P. 209.5; and (3) R.M.P. 221.6 to R.M.P. 231.3 (Figure 1.3). All disturbance types, with the exception of false start roads, were sampled in this plant community.

Table 4.7: Average cover values for the undisturbed Betula glandulosa-Cladonia stellaris-Moss Community (n=14)

Species	Cover	n	Species	Cover	n	Species	Cover	n
BET GLAN	16.27	11	MER PANI	0.25	1	SIL ACAU	0.01	1
STELL SP	0.01	1	ANT MONO	0.48	2	ARN ALPI	0.19	1
ART ARCT	5.30	2	PET FRIG	0.75	2	SENEC SP	1.10	2
SEN LUGE	0.01	1	JUN COMM	0.01	1	CAR BRUN	0.09	3
CAR PODO	0.14	1	CAR SCIR	0.14	1	EMP NIGR	1.21	4
EQU ARVE	1.20	2	ARC ALPI	4.34	1	ARC UVA-	2.80	1
CAS TETR	0.01	3	LED GROE	4.95	1	VAC ULIG	3.53	2
VAC VITI	0.32	12	GEN GLAU	0.08	2			
CAL CANA	3.51	2	DES CAES	0.50	1	FES ALTA	2.12	4
LUZ PARV	0.60	2	HED ALPI	0.01	1	LYC ALPI	0.01	2
LYC CLAV	0.01	1	EPI ANGU	0.60	4	POL ACUT	0.88	3
POL VIVI	0.01	2	ANE NARC	0.20	2	ANE PARV	0.01	1
THA ALPI	0.14	1	DRY INTE	0.75	1	POT FRUT	0.01	1
RUB ACAU	0.01	4	RUB CHAM	0.01	1	SIB PROC	0.01	3
SPI BEAU	0.01	1	SAL GLAU	0.01	1	SAL PLAN	2.88	5
SAL RETI	0.80	3	PEDIC SP	1.10	2	PED LABR	0.01	1
VAL CAPI	1.20	2	ALE OCHR	0.01	1	CET CUCU	0.31	7
CET ISLA	0.89	12	CET LAEV	0.25	1	CET NIVA	2.55	9
CET PINA	0.37	12	CET RICH	0.36	11	CET SEPI	1.92	1
CLA ARBU	4.10	4	CLA MITI	36.32	5	CLA RANG	4.18	11
CLA STEL	25.82	10	CLA AMAU	1.10	1	CLA BELL	0.01	3
CLA CARN	0.01	6	CLA CENO	0.0	1	CLA COCC	0.35	8
CLA CORN	0.70	4	CLA CRIS	0.0	5	CLA DEFO	0.00	7
CLA FIMB	0.01	4	CLA GONE	0.08	8	CLA G DI	0.44	3
CLA G GR	1.21	4	CLA MACA	0.0	2	CLA MAJO	0.01	1
CLA PLEU	0.0	2	CLA POCI	0.70	1	CLA SUBF	0.01	5
CLA SUBU	0.09	4	CLA UNCI	0.01	3	CLA VERT	0.0	1
CLAD SPP	0.30	8	DAC ARCT	0.01	1	DAC BERI	0.85	1
ICM ERIC	0.01	1	LEC GRAN	0.05	3	NEP ARCT	0.01	5
OCH ANDR	0.14	1	PAR SEPT	0.19	1	PAR AMBI	0.23	6
PAR HYPE	0.67	4	PEL APHT	0.32	10	PEL CANI	0.02	2
PEL PULV	0.01	2	SOL CROC	0.04	7	STE ALPI	0.01	1
STE PASC	2.68	10	UMB HYPE	0.01	1	UMB PROB	0.01	1
SOIL LIC	0.65	1	HEPATICS	0.0	3	MOSS SPP	8.70	10
AUL PALU	8.02	4	CER PURP	0.01	1	DICRANUM	0.01	1
DRE UNCI	0.01	1	HYL SPLE	0.00	3	PLE SCHR	0.0	6
POL COMM	10.59	8	POL JUNI	1.01	3	POL PILI	0.01	2
POL STRI	0.33	7						

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

All of these disturbances had less *Betula glandulosa* cover than was found in control areas (Appendix VI,H). In addition to this, *Cladonia mitis, C. rangiferina, C. stellaris, Cetraria nivalis, Stereocaulon paschale* and *Polytrichum commune* all had notably less cover on at least four of the disturbance types sampled (Table 4.3) but none of these species were restricted to undisturbed areas. *Festuca altaica* was the only species with higher cover values on four or more disturbance types than in control stands.

Species richness was lower than that of the control stands on roads, gravel pits and oil spills but greater on bladed trails, bulldozer tracks, camp yards and gravel pit access roads in this community (Table 4.5). Similarity coefficients indicate that the flora of the bulldozer track plant community was most similar to that of the control, while that of the camp yard was least similar (Table 4.4).

The removal of the dominant shrub, *Betula glandulosa*, and the continuous lichen cover opened the area to colonizing species that formed new plant communities on disturbances. These new assemblages of plants had many traits in common with their control stands. However, the dominant species had changed. This created greater environmental diversity in this portion of the study area where large tracts of *Betula glandulosa-Cladonia stellaris*-Moss plant communities dominated the landscape. The alterations resulting from the CANOL disturbances provide habitat for species such as *Salix alaxensis* and *S. planifolia* that otherwise have more restricted ranges in this plant community or are found only on natural disturbances.

4.3.1.2 Decumbent Shrub Tundra

In Decumbent Shrub Tundra plant communities, shrub layers were less than 30 cm in height, covering at least 50% of the area under plant cover. In the study area, this type of tundra was dominated by low-growing or prostrate *Salix* and *Dryas* species. Floristically it can be divided into *Salix barrattiana*–Moss, *Salix polaris-Dactylina beringica* and *Dryas integrifolia-Carex* Species plant communities.

This type of tundra was present in every ecosection. The *Salix barrattiana*–Moss community was common where soil moisture was high along small stream bottoms or in

protected seepage areas at lower elevations. This contrasts sharply with other plant communities which were common at higher elevations and in exposed sites where winter snow cover was thin and discontinuous. In these cases, soils were generally well-drained.

Salix barrattiana- Moss Community

The 20 to 30 cm *Salix barrattiana* shrub canopy was generally dense, over a plant assemblage dominated by broad-leaved forbs and *Salix reticulata* (Table 4.8). Moss species in this plant community (Table 4.4) included: *Tortula norvegica, Hypnum lindbergii, Brachythecium starkei, Bryum pseudotriquetrum,* and *Drepanocladus uncinatus.*

Five control stands were sampled in this plant community between R.M.P. 191.2 and R.M.P. 203.8 in the upper Ekwi River-Caribou Pass-Intga River section of the western study area (Figure 1.3). Road, bladed trail, bulldozer track, gravel pit and oil spill disturbance sites were sampled.

Species richness was greater than that of the controls on all disturbances with the exception of roads and oil spills (Table 4.5). The species composition of the road plant community was most different and that of the bulldozer tracks most similar to that of the controls (Table 4.4). Floristic similarity to control stands was generally low. If the shrub canopy acts to moderate conditions beneath it in a similar fashion to that postulated for the *Salix reticulata-Salix lanata* plant community, then this would explain the low similarity coefficients. This seems probable and is supported indirectly by the fact that ground cover species such as *Salix reticulata* are abundant in each plant community. However, conditions vary, as is evidenced by the fact that *Salix reticulata* had greater cover on all disturbances than in the controls while in Erect Deciduous Shrub Tundra it's cover was lower on all but bulldozer tracks (Table 4.3) Perhaps the structurally reduced shrub cover in Decumbent Shrub Tundra provided less shelter than did the taller shrubs, so that ground cover ecotypes in this community were better adapted to the exposed conditions on most disturbances.

Salix barrattiana, Mertensia paniculata, Thalictrum alpinum, Arctagrostis latifolia, Polemonium acutiflorum, Aconitum delphinifolium

Table 4.8: Average cover values for the undisturbed <u>Salix</u> <u>barrattiana</u>-Moss Plant Community (n=5)

Species	Cover	n	Species	Cover	n	Species	Cover	n
MER PANI	7.05	4	MYO ALPE	0.25	4	CER BEER	0.09	4
STELL SP	0.01	4	STE LAET	0.19	4	ART TILE	0.60	4
PET FRIG	1.87	4	SEN LUGE	0.14	4	RHO INTE	0.14	4
CAR PRAT	0.01	4	COMPO SP	0.90	4	DRA LONG	0.09	4
EUT EDWA	0.01	4	CAR A AQ	34.50	1	EQU ARVE	4.07	4
GEN PROP	0.04	4	ARC LATI	2.12	4	DES CAES	1.92	4
AST UMBE	1.05	4	POL ACUT	7.51	4	POL VIVI	0.19	4
RUM ARCT	0.75	4	CLA TUBE	0.01	4	ACO DELP	2.90	4
ANE PARV	0.64	4	RAN SULP	0.01	5	THA ALPI	2.58	4
POT FRUT	0.75	1	SAL BARR	30.10	5	SAL GLAU	0.75	1
SAL MYRT	0.01	1	SAL RETI	2.86	5	CHR TETR	0.01	4
PAR KOTZ	0.09	4	PED SUDE	0.01	4	VAL CAPI	0.01	4
VIOLA SP	1.92	4	CET PINA	0.04	4	CLA CHLO	0.14	4
PEL APHT	0.01	4	MOSS SPP	16.81	5	BRA STAR	0.0	4
BRYACEAE	0.0	3	BRY PSEU	0.0	5	CAM STEL	0.0	3
DRE UNCI	0.0	4	HYP BAMB	0.0	3	HYP LIND	0.0	4
PHI TOME	0.0	3	POH CRUD	0.0	3	TOR NORV	0.0	4

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

and *Equisetum arvense* had less cover than controls on all of the disturbance types in this community (Appendix VI, E and Table 4.3). Of these, the last three species were restricted to undisturbed sites only and therefore must have been particularly sensitive to disturbance or incapable of colonizing the types of disturbances here. Even after 34-36 years, no one species consistently recolonized disturbed sites, indicating that conditions on disturbances were severely limiting to plant colonization.

The diversity of species in disturbance plant communities has produced low similarity coefficients, indicating that disturbed sites were substantially different from their controls. Disturbances that resulted in the lowering of surfaces have greater species richness than do their controls while elevated roads and oil spills support fewer species (Table 4.5). Roads can be substantially drier as a result of increased runoff and reduced infiltration and the oil seal on the surface of oil spills would also create very dry substrates. Considerable time will probably be required before these conditions change sufficiently to allow these disturbance plant communities to become more similar to those of the controls, if this is indeed possible.

Salix polaris - Dactylina beringica Community

Salix polaris formed almost pure stands in this plant community (Table 4.9). A number of lichens were also present. However, these were much less abundant than the willow.

Two control stands, located on the Mackenzie Mountain Barrens between R.M.P. 213 and R.M.P. 213.5 (Figure 1.3), were sampled with associated road, bulldozer track, gravel pit and gravel pit access road disturbances. *Salix polaris* was the only plant species to have a greater cover on all of the disturbance types than in the controls (Appendix VI, G). No species had greater cover than controls on all site types but *Trisetum spicatum* and miscellaneous moss species were never collected from undisturbed areas and composed a significant portion of the cover on road, bulldozer track and gravel pit access road sites (Table 4.3).

Table 4.9: Average cover values for the undisturbed *Salix polaris-Dactylina beringica* Plant Community (n=2)

Species	Cover	n	Species	Cover	n	Species	Cover	n
MIN BIFL	0.01	2	ANT MONO	0.25	2	ART ARCT	0.25	2
PET FRIG	0.04	2	RHO INTE	0.01	2	CAR PODO	0.19	2
GEN GLAU	0.01	2	POA ARCT	0.85	2	LUZ ARCU	0.04	2
LUZ PARV	0.04	2	POL ACUT	0.01	2	ANE NARC	0.19	2
RAN ESCH	0.01	2	SIB PROC	0.01	2	SAL POLA	29.00	2
SAL RETI	0.01	2	PED SUDE	0.01	2	CET ISLA	0.25	2
CET NIVA	0.09	2	CET RICH	0.04	2	CLA MITI	0.54	2
CLA COCC	0.25	2	CLA ECMO	0.80	2	CLA GONE	0.25	2
DAC BERI	0.90	2	NEP ARCT	0.09	2	NEP EXPA	0.80	2
PEL APHT	0.54	2	SOL CROC	0.09	2	STE ALPI	0.34	2
PLE SCHR	0.0	2	POL COMM	0.0	2	POL STRI	0.0	2
RHA CANE	0.0	2						

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

Species richness was lower than controls on roads and gravel pit access roads in this plant community but higher on the bulldozer track and gravel pit sites. Similarity coefficients indicate that the species composition of the bulldozer track plant community was most similar to that of the controls while that of the road was most different (Table 4.4). With a decline in species richness (Table 4.5) and low floristic similarity to control stands, it appears that disturbances here have long-term consequences that are biologically undesirable. This indicates that this plant community does not respond well after disturbances. However, it is noteworthy that *Salix polaris* successfully recovered and that this species was also the dominant plant species in control stands.

Dryas integrifolia - Carex Species Community

This plant community had a diversity of species, however, *Dryas integrifolia* formed a carpet under all. There was little moss cover, in response to the general dryness and excessive exposure at these sites. *Carex* species were present and collectively occupied enough area to be classified as subdominants (Table 4.10). The most common sedges were *Carex rupestris, C. misandra, C. scirpoidea* and *C. membranacea.*

Three control stands were sampled in this plant community. Two of these were located on the Plains of Abraham between R.M.P. 78.9 and R.M.P. 85.3 and one was found in the Intga River valley at R.M.P. 201.5 (Figure 1.3). Road, bladed trail, gravel pit and gravel pit access road disturbances were sampled within this community.

Dryas integrifolia and miscellaneous lichen species had much lower cover values on all disturbance types than in the undisturbed areas (Appendix VI, K and Table 4.3) Several species had notably higher cover on disturbed sites but none of these were common to all disturbances. With removal of the dominant control species and recolonization by fewer species, it is apparent that the disturbance plant community is a simplification of that of the undisturbed area.

Table 4.10: Average Cover Values for the *Dryas integrifolia*-*Carex* spp. Plant Community (n=3)

Species	Cover	n	Species	Cover	n	Species	Cover	n
MIN ARCT	0.19	2	MIN R EL	0.19	1	MIN ROSS	0.01	1
SIL ACAU	0.60	1	ANT DENS	0.01	1	ARN ALPI	0.01	1
CHR INTE	0.38	3	SEN ATRO	0.01	1	SEN CYMB	0.14	1
BRA PURP	0.01	1	DRA CORY	0.01	1	PAR NUDI	0.01	2
CAREX SP	15.00	1	CAR ATFU	0.01	1	CAR CAPI	0.54	1
CAR MEMB	0.05	2	CAR MICG	0.01	1	CAR MISA	1.98	2
CAR PODO	0.70	1	CAR RUPE	7.00	1	CAR SCIR	0.70	2
ERI ANGU	0.50	1	KOB SIMP	2.26	2	SCI CAES	1.56	1
EQU VARI	0.01	1	ARC ALPI	3.47	2	CAS TETR	0.01	2
RHO LAPP	0.34	1	POA SP	0.04	1	LYCOP SP	0.54	1
JUNCUS	0.14	1	JUN BIGL	0.10	2	JUN ALBE	0.25	1
HED ALPI	0.60	1	PIN VULG	0.83	2	LLO SERO	0.01	2
TOF PUSI	0.98	2	ZYG ELEG	0.75	1	EPI LATI	0.01	1
PAP KEEL	0.01	1	POL VIVI	0.11	3	WOO GLAB	0.01	1
AND CHAM	0.33	3	ANE PARV	0.64	2	THA ALPI	0.49	3
DRY INTE	27.67	3	POT FRUT	3.18	2	SAL ARCT	0.10	2
SAL DODG	0.16	2	SAL POLA	0.01	1	SAL A XP	0.04	1
SAL RETI	0.13	2	PAR FIMB	0.01	1	SAX AIZO	1.01	2
SAX OPPO	1.75	3	PED CAPI	0.80	2	PED LANA	0.09	1
SEL SELA	0.01	1				CET CUCU	0.80	1
CET TILE	0.08	2	CLA POCI	0.01	1	DAC RAMU	0.0	1
THA SUBU	0.44	1	CRUSTOSE	0.09	1	SOIL LIC	1.41	1
SAX LICH	3.00	1	MOSS SPP	0.58	3	BLE TRIC	0.0	1
CAT NIGR	0.0	1	DIT FLEX	0.0	1	HYP BAMB	0.01	2
TOR RURA	0.0	1	CIN STYG	0.0	1			

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

Species richness was less on all disturbances in this plant community than in control stands (Table 4.5). The average similarity coefficient was not low. The species composition of the bulldozer tracks was most similar to that of the controls while the gravel pit plant community had the least in common with the undisturbed area (Table 4.4).

4.3.1.3 Sedge Meadow Tundra

Sedge Meadow Tundra was dominated by herbaceous plants, primarily *Carex* and *Eriophorum* species. In areas where soil moisture was excessive as a result of topographic depressions or impeded drainage, this type of tundra was common. The most extensive areas of Sedge Meadow Tundra occurred over tills in the western portion of the study area.

Carex membranacea - Sphagnum Species Community

This wetland was found in the Bolstead Creek–Devil's Pass Ecosection. The oil spill in this plant community affected only the broader area where it extended down a slope into the wetland. Large tussocks and small mounds surrounded by standing water were common. These contained frozen material in late August of 1978 and 1979. *Carex membranacea* and *Eriophorum vaginatum* were the most abundant vascular plants with *Sphagnum* forming a high percentage of the ground cover (Table 4.11).

The areas affected by the oil spill in this palsa fen varied greatly in their responses. Consequently, two stands representing two extremes were sampled: (1) a denuded site and (2) a site with relatively high plant cover. The site with the greater plant cover was located on a raised area and was probably less affected by the oil than the low–lying, drainage areas where the denuded site occurred. Only one area, located west of Devil's Pass at R.M.P. 111.5 (Figure 1.3), was sampled in this plant community (Table 4.11).

Eriophorum vaginatum had much less cover on the oil spills than in the undisturbed areas and *Carex membranacea* and *Andromeda polifolia* were both present in the control sites but absent from the oil spill areas (Appendix VI, A.). *Eriophorum angustifolium* was the only vascular plant with

Table 4.11: Average cover values for the undisturbed Carex membranacea-Sphagnum Plant Community (n=1)

Species	Cover	n	Species	Cover	n	Species	Cover	n
BET GLAN	0.60	1	CAR MEMB	25.51	1	ERI ANGU	1.41	1
ERI VAGI	8.90	1	AND POLI	2.70	1	LED DECU	0.60	1
LED GROE	0.01	1	VAC ULIG	0.01	1	VAC VITI	0.01	1
RUB CHAM	0.01	1	PED LABR	0.01	1	CET CUCU	2.25	1
CLA ARBU	0.01	1	CLA RANG	2.14	1	CLA GONE	0.04	1
CLA SUBU	0.01	1	CLA UNCI	0.01	1	ICM ERIC	0.01	1
RHI INAR	0.01	1	OCH GEMI	0.01	1	HEPATICS	0.01	1
MOSS SPP	2.70	1	POLYT SP	0.14	1	CAL STRA	0.01	1
DITRICHU	0.01	1	POL COMM	0.01	1	SPHAGNUM	22.00	1

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

greater cover on these sites than in the undisturbed areas. This has also been noted by Walker and others (1978) on recent spills in the Prudoe Bay area. *Cetraria cucullata, Cladonia rangiferina, Sphagnum* species and miscellaneous mosses were all important components of the undisturbed area but were absent from the oil spills. These findings do not agree with those of Hutchinson and Hellebust (1978) where *Polytrichum* spp., *Cetraria* spp. and *Cladonia cornuta* were found to be unaffected or were recolonizing after 3 years. Terrestrial algae (*Nostoc* spp.) were absent from the control site but accounted for approximately 8.5% of the total cover on one spill (Appendix VI, A). The flora contained only 28% as many species as were found on the control site and the species composition of the disturbed and undisturbed sites differed greatly (Table 4.4). Thirty-four years following the initial oil spill, the plant community on the site remains considerably simplified and reduced in cover (Table 4.5).

Miscellaneous Mosses - Carex podocarpa Community

This plant community was dominant on the Mackenzie Mountain Barrens in relatively flat, poorly drained areas. Extensive areas of palsas and peat plateaus were common in this wetland-dominated terrain. However, the plant communities on these features were not always sirnilar to those of the surrounding area.

Carex podocarpa was the dominant vascular plant. However, *Carex aquatilis* was also common (Table 4.12). *Artemisia arctica, Anemone narcissifolia, Petasites frigida, Gentiana glauca, Rhodiola integrifolia, Polemonium acutiflorum* and other broad-leaved forbs were present in most of the stands that were sampled.

Common mosses in this plant community included: *Aulacomnium palustre, Dicranum* sp., *Drepanocladus uncinatus, Hylocomnium splendens, Pleurozium schreberi, Polytrichum commune, P. juniperinum, P. strictum,* and *Rhacomitrium canescens.* 'Miscellaneous Lichens' included: *Cetraria cucullata, C. islandica, C. richardsonii, Cladonia arbuscula, C. cenotea, C. ecmocyna, C. gracilis dilatata, C. gracilis gracilis, C. pleurota, Dactylina*

Table 4.12: Average cover values for the undisturbed Miscellaneous Mosses-Carex spp. Plant Community (n=15)

Species	Cover	n	Species	Cover	n	Species	Cover	n
BET GLAN	0.01	1	MYO ALPE	0.01	3	CER BEER	0.10	3
MIN BIFL	0.04	1	STELL SP	0.02	3	ANT MONO	0.22	8
ART ARCT	1.70	10	PET FRIG	0.10	10	PET HYPE	0.40	2
SEN ATRO	0.06	4	SEN LUGE	0.19	1	SEN TRIA	0.10	3
SEN YUKO	0.04	3	TAR ALAS	0.01	1	RHO INTE	0.74	10
DRA LONG	0.01	1	DRA ALBE	0.02	2	CAREX SP	1.64	3
CAR A ST	9.01	6	CAR MICH	0.01	1	CAR PODO	6.28	12
ERI ANGU	0.01	4	EMP NIGR	0.01	1	EQU ARVE	0.01	1
EQU SCIR	0.01	1	CAS TETR	1.82	6	KAL P MI	0.25	1
LED GROE	0.01	3	VAC ULIG	0.01	1	VAC VITI	0.75	1
COR PAUC	0.01	2	GEN GLAU	0.15	10	ARC LATI	4.76	3
DES CAES	7.28	2	SAL COMM	2.02	3	FES ALTA	4.53	1
POA PORS	6.50	2	TRS SPIC	0.01	1	LUZ ARCU	0.61	8
LUZ PARV	3.05	2	LLO SERO	0.01	1	LYC ALPI	0.02	5
LYC SELA	0.01	5	POL ACUT	0.33	11	POL VIVI	0.11	7
RUM ARCT	0.39	2	CLA TUBE	0.10	4	PYROL SP	0.01	1
ANE NARC	0.42	10	ANE PARV	1.52	2	ANE RICH	0.54	2
RAN ESCH	0.01	1	RAN NIVA	0.10	2	RAN SULP	0.40	2
GEU ROSS	4.53	2	RUB ACAU	0.14	2	SIB PROC	0.10	5
SAL ARCT	7.46	1	SAL PLAN	1.98	7	SAL POLA	1.32	12
SAL A XP	0.01	1	SAL RETI	0.74	5	CHR TETR	0.09	2
PAR KOTZ	0.01	1	SAX FOLI	0.04	2	SAX HIER	0.32	2
SAX PUNC	0.04	1	LAG STEL	0.16	5	PEDIC SP	0.01	1
PED SUDE	0.08	8	VIO EPIP	0.01	2	TER ALGA	0.01	1
			CET CUCU	0.01	1	CET ISLA	0.99	11
CET LAEV	0.0	1	CET NIVA	0.19	1	CET RICH	0.10	9
CLA ARBU	1.05	3	CLA RANG	2.44	7	CLA STEL	10.91	1
CLA BELL	0.0	4	CLA CARN	0.0	2	CLA CENO	0.01	1
CLA COCC	0.00	12	CLA CORN	0.01	2	CLA CRIS	1.01	2
CLA DEFO	0.0	4	CLA ECMO	0.58	6	CLA FIMB	0.01	2
CLA GONE	0.0	6	CLA G DI	0.01	2	CLA G GR	0.01	4
CLA META	0.0	1	CLA PLEU	0.01	1	CLA UNCI	0.0	1
CLAD SPP	0.37	10	DAC ARCT	0.11	7	DAC BERI	1.30	3
LEC GRAN	0.25	1	NEP ARCT	0.30	2	NEP EXPA	0.04	1
PEL APHT	0.74	8	PEL MALA	0.01	2	PEL PULV	0.75	1
SOL CROC	0.63	6	STE PASC	0.90	6	STE TOME	0.09	1
UMB HYPE	0.01	1	LEP NEGL	1.00	1	HEPATICS	0.01	7
MOSS SPP	41.70	15	AULAC SP	0.0	2	AUL PALU	0.0	6
BRACH SP	0.0	2	BRA ERYT	0.0	1	BRYUM SP	0.0	3
DICRANUM	0.0	6	DRE UNCI	0.0	6	HYL SPLE	0.0	9
PLA ELLI	0.0	1	PLE SCHR	0.0	5	POG ALPI	0.0	4
POL COMM	0.0	6	POL JUNI	0.0	4	POL STRI	0.0	4
RHA CANE	0.0	6	SPHAGNUM	0.0	2	TOMENTHY	0.0	2
TOM NITE	0.0	3	TOR NORV	0.0	1	CIN STYG	0.0	1
CYRTOMNI	0.0	2	PLA CUSP	0.0	2	RHI PSEU	0.0	2

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

arctica, Nephroma arctica, Solarina crocea and *Stereocaulon tomentosa.*

Fifteen stands were sampled in this plant community, all in the western portion of the study area between R.M.P. 212 and R.M.P. 216.5 on the Mackenzie Mountain Barrens (Figure 1.3). Disturbances included road, bladed trail, bulldozer track, gravel pit and gravel pit access road.

When present, the following species consistently had lower cover on the various disturbances than in the controls (Appendix VI, B): *Cassiope tetragona, Carex aquatilis stans, Festuca altaica, Geum rossii, Cladonia crispata, C. rangiferina, C. stellaris, Dactylina beringica* and miscellaneous moss species (Table 4.3). Many of these taxa were among the most abundant plants on control sites. Cover was consistently greater for *Trisetum spicatum, Epilobium* species, *Stereocaulon alpinum, S. saxatile,* and *S. tomentosum.* The species in this latter group were rarely found in undisturbed areas and therefore were much more common in this area as a consequence of the disturbances.

Similarity coefficients showed the species composition of the bulldozer track plant community to be least different from that of the control, while those on the roads and gravel pit access roads were least similar (Table 4.4). Bulldozer tracks and gravel pit access roads had lower species richness while roads, bladed trails and gravel pits had greater numbers of species in comparison to the control sites (Table 4.5). No general statement can be made regarding the recovery of this plant community since responses appear to be very specific to each disturbance type.

<u>Carex</u> spp. - <u>Kobresia</u> <u>simpliciuscula</u> Community

This plant community occupied snow melt and seepage areas only and was never extensive. These low-angled slopes had little micro-topographic variation and plant cover was seldom continuous. During late July and August, following melt of late-lying snow patches, the ground surface was generally dry, except when there was frequent rain. *Carex membranacea* was the most abundant plant while *C. misandra* and *C. podocarpa* had only slightly less cover (Table 4.13). *Kobresia simpliciuscula* and *Eriophorum angustifolium* were

Table 4.13: Average cover values for the Carex spp.-Kobresia simpliciuscula Plant Community (n=1)

Species	Cover	n	Species	Cover	n	Species	Cover	n
MIN ARCT	0.01	1	MIN R EL	0.01	1	SEN ATRO	0.01	1
SEN CYMB	0.01	1	CAR MEMB	11.52	1	CAR MISA	9.57	1
CAR PODO	9.11	1	ERI ANGU	2.02	1	ERI CALL	0.25	1
KOB SIMP	3.15	1	CAS TETR	0.01	1	JUN ALBE	0.54	1
PAP RADI	0.04	1	POL VIVI	0.04	1	THA ALPI	0.14	1
DRY INTE	0.34	1	DRY OCTO	0.14	1	SAL ARCT	0.09	1
SAL RETI	0.14	1	PED LANA	0.04	1	TER ALGA	0.14	1
CET NIVA	0.04	1	CET TILE	0.01	1	SOL BISP	0.04	1
SOIL LIC	1.10	1	HEPATICS	0.09	1	MOSS SPP	1.92	1
CAM STEL	0.01	1	DIT FLEX	0.01	1	HYP BAMB	0.01	1

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

also common.

One control site, located at R.M.P. 80.5 on the Plains of Abraham, was sampled in this plant community (Table 4.3). Disturbances include a road and a gravel pit site.

In the gravel pit, cover was notably less than that of the control for *Carex membranacea, C. misandra, C. podocarpa* and *Eriophorum angustifolium* (Appendix VI, D and Table 4.3). None of these species was found growing on the road. *Salix alaxensis* was absent from the control but had cover values of 8% and 12% on the road and gravel pit sites respectively. Furthermore, this erect shrub layer was not present in control stands.

Species composition on the road was most like that of the control (Table 4.4). Both the road and gravel pit had greater species richness than the control (Table 4.5). This reflected a substantial increase in cover by woody species on the disturbed sites in comparison to the predominantly herbaceous species of the control sites.

With greater species richness and structural complexity enhanced, it appears that these disturbances have produced a diversity of habitats previously not available. These alterations in plant community characteristics are often considered to be ecologically desirable since the more species that are present, the greater the stability of that community. Furthermore, increased structural complexity ensures that a more efficient use of the areas's resources is achieved. As available resources (e.g. radiation, moisture) can be utilized by more than one layer, the prodiction of greater biomass is theoretically possible on sites where several layers occur. Also, animals relying on these plants will have a greater choice when selecting forage and will recieve greater shelter and cover from the disturbance communities which contain erect shrubs.

4.3.1.4 Lichen Heath Tundra

Lichen Heath Tundra was dominated by *Dryas integrifolia* and fruticose lichens with an important ericaceous shrub component less than 30 cm in height. This community was found most frequently over tills and colluvium but was also noted covering bedrock

where sufficient moisture was available. It was most common on north-facing slopes at lower elevations in the eastern portion of the study area. The Blue Mountain and Bolstead Creek-Devil's Pass Ecosections contained the most extensive areas of Lichen Heath Tundra, although it was also common in the Macmillan Pass area in the Ekwi-Intga-Tsichu River Valleys Ecosection.

Dryas integrifolia - Cassiope tetragona Community

Dryas integrifolia was the most abundant plant in this type of tundra with a mean cover value of 36%. However, due to the complete plant cover and significant ericaceous shrub and fruticose lichen components, this community was classified as Lichen Heath Tundra. Common ericaceous shrubs included: *Cassiope tetragona, Vaccinium uliginosum, Rhododendron lapponicum* and *Andromeda polifolia*. Carices were also common. Common lichens included several species of *Cetraria* as well as *Alectoria ochroleuca*. Moss species included: *Tomenthypnum nitens, Rhacomitrium lanuginosum, Encalypta procera, Tortula latifolia* and *Hypnum bambergii*. The saxicolous lichens collected were *Evernia perfragilis*, *Lecanora epibyron* and *Lecidea stigmatea.* The *Dryas integrifolia-Cassiope tetragona* plant community supported a larger number of species than did any other plant community.

Ten control stands were sampled in the following areas: (1) R.M.P. 56.8, (2) R.M.P. 79.9 to R.M.P. 83.4 on the Plains of Abraham, (3) R.M.P. 92.8, (4) R.M.P. 106.6 to R.M.P. 110.2 in the Bolstead Creek valley and (5) R.M.P. 212.5 on the Mackenzie Mountain Barrens (Figure 1.3). The only type of disturbance not sampled within this community was the camp yard.

Dryas integrifolia was the only plant species to have notably less cover on the disturbances sampled than on the control sites (Appendix VI, J and Table 4.3). However, several of the dominant control species, including *Alectoria ochroleuca, Cassiope tetragona, Carex petricosa, C. rupestris* and *Potentilla biflora* had notably less cover on five or more disturbance types. The first two species in this group tended to be restricted to undisturbed areas. *Salix alaxensis* was the only species with notably higher cover values on five or more disturbance types than in the control stands.

Species richness was less than that of the controls on all disturbance types in this plant community (Table 4.5). Insufficient data were collected to determine the species richness of the bulldozer track plant community. Similarity coefficients indicate that the bladed trail flora is most similar to that of the undisturbed area while the gravel pit access road plant community differed most from that of the control (Table 4.4).

Generally floristic similarity with control stands was not low. The reduction in species richness and similarity coefficient data show that long–term recovery is proceeding. However, it is difficult to describe the rate of this process since little comparative data are available from other studies. In human terms, 34–36 years is a long time. However, until data on the duration of succession in this environment are available it is difficult to discuss this in a relative sense. If the age of control stand shrubs can be used as an indication (Section 4.3.2), this time span is short and recovery rates should not be considered slow. In addition, the presence of *Salix alaxensis* has increased structural diversity.

4.3.1.5 Fruticose Lichen Tundra

Fruticose Lichen Tundra was similar to Lichen Heath Tundra in many respects. However, it lacked a shrub layer and fruticose lichens were the most abundant plants. Generally this community occupied well–drained areas on alluvium and colluvium. When large scale patterned ground was present, this community generally occupied the site, with lichen encrusted cobbles protruding through the fruticose lichen cover. In protected areas, Fruticose Lichen Tundra was found only on excessively drained sites where coarse–grained deposits predominated. Generally, it was more typical of high, exposed sites in the Blue Mountain, Bolstead Creek–Devil's Pass and Ekwi–Intga–Tsichu River Valleys Ecosections.

<u>Cladonia</u> <u>stellaris</u> - <u>Alectoria</u> <u>ochroleuca</u> Community

This plant community was dominated by several species of fruticose lichens (Table 4.15). The most common of these were *Cladonia stellaris, C. rangiferina, Alectoria ochroleuca, Cetraria cucullata, C. nivalis,* and *C.*

Table 4.14: Average cover values for the undisturbed <u>Dryas</u> <u>integrifolia</u>-<u>Cassiope</u> <u>tetragona</u> Plant Community (n=10)

Species	Cover	n	Species	Cover	n	Species	Cover	n
BET GLAN	0.54	4	OTHR VAS	10.50	1	MEL APET	0.01	2
MIN ARCT	0.29	4	MIN R EL	0.14	4	MIN ROSS	0.26	2
SIL ACAU	1.53	8	ANT DENS	0.04	1	ARN ALPI	0.38	2
CHR INTE	0.02	4	SAU ANGU	0.05	3	SEN ATRO	0.02	2
SEN LUGE	0.01	1	SEN CYMB	0.22	2	SOL MULT	0.01	1
BRA PURP	0.01	2	BRA RICH	0.34	1	CAR BELL	0.01	1
DRA CORY	0.01	2	PAR NUDI	0.02	5	CAR ATFU	0.38	2
CAR CAPI	0.01	1	CAR GLAC	1.26	1	CAR MEMB	0.01	3
CAR MISA	1.09	4	CAR NARD	1.26	1	CAR PETR	1.75	4
CAR PODO	14.50	1	CAR RUPE	8.59	5	CAR SCIR	3.11	8
CAR VAGI	0.01	1	ERI ANGU	4.71	5	ERI CALL	0.25	1
KOB MYOS	0.01	1	KOB SIMP	0.76	5	EMP NIGR	0.01	1
EQU VARI	0.94	2	AND POLI	0.25	5	ARC ALPI	1.54	5
CAS TETR	9.40	9	LED GROE	0.01	2	RHO LAPP	1.00	6
VAC ULIG	2.43	6	GEN PROP	0.01	1	ARC LATI	0.14	1
ELY INNO	0.01	1	FES ALTA	0.01	3	TRS SPIC	0.01	1
JUN BIGL	0.01	2	JUN ALBE	0.18	3	LUZ NIVA	0.30	2
LUZ PARV	0.01	1	TRI MARI	0.01	1	AST UMBE	0.01	1
HED ALPI	0.17	3	HED MACK	1.26	2	OXYTR SP	0.13	3
OXY JORD	0.01	1	OXY NIGR	0.09	2	OXY SHEL	0.01	1
PIN VULG	0.01	4	LLO SERO	0.01	1	TOF PUSI	0.34	8
LYC SELA	0.01	1	BOT LUNA	0.01	1	PAP KEEL	0.02	4
PIC GLAU	0.01	2	ARM MARI	0.01	1	POL BIST	0.47	2
POL VIVI	0.47	8	WOO GLAB	0.01	1	AND CHAM	0.33	6
PYR ASAR	0.01	5	PYR SECU	0.01	1	ANE PARV	0.12	6
THA ALPI	0.33	9	DRY INTE	36.50	9	DRY OCTO	16.43	2
POT BIFL	4.53	5	POT FRUT	0.01	4	SAL ALAX	0.01	3
SAL ARCT	1.63	3	SAL DODG	0.31	3	SAL POLA	0.01	2
SAL A XP	0.01	2	SAL RETI	1.25	8	SAX AIZO	0.01	3
SAX HIRC	0.01	2	SAX OPPO	0.98	7	PED CAPI	1.32	6
PED LANA	0.05	6	PED ARCT	0.04	1	PED SUDE	0.04	5
			ALE OCHR	3.20	7	ASA CHRY	0.65	3
CET CUCU	3.47	8	CET DELI	0.68	2	CET ERIC	1.21	3
CET ISLA	2.21	6	CET LAEV	0.50	1	CET NIVA	2.41	9
CET PINA	0.01	2	CET RICH	0.36	4	CET TILE	1.91	9
CLA ARBU	0.78	6	CLA RANG	0.80	1	CLA STEL	0.65	2
CLADO SP	0.01	1	CLA ACUM	0.01	1	CLA CHLO	0.0	1
CLA G GR	0.10	2	CLA MAJO	0.0	1	CLA PHYL	0.0	1
CLA POCI	0.23	6	CLA PYXI	0.13	2	CLA UNCI	0.34	1
CLAD SPP	0.34	1	COR ACUL	0.01	1	COR DIVE	0.01	1
DAC ARCT	0.76	7	DAC BERI	0.44	1	DAC RAMU	0.12	4
LEC EPIB	0.50	4	LEC URCE	1.53	3	OCH ULIG	1.92	2
PEL APHT	0.01	1	PEL CANI	0.01	2	PER DACT	0.29	1
POL SEND	1.46	1	SOL BISP	0.05	8	THA SUBU	1.55	8
THA VERM	0.01	1	CRUSTOSE	9.69	1	SOIL LIC	2.68	7
SAX LICH	6.60	4	RIN ROSI	0.80	1	VER MURA	0.0	2
LEC STIG	0.07	4	POL INTE	0.0	1	OCH INAE	0.01	1

Table 4.14 continued

HEPATICS	0.01	3	MOSS SPP	5.32	10	AUL ACUM	0.0	1
ENCALYPT	0.0	1	CAM STEL	0.0	1	CER PURP	0.0	1
CIR CIRR	0.01	1	CRY HYME	0.01	2	DICRANUM	0.0	1
DITRICHA	0.0	1	DIT FLEX	0.00	4	DREPANOC	0.01	1
DRE REVO	0.01	1	HYL SPLE	0.01	4	HYPNUM	0.01	2
HYP BAMB	0.01	9	HYP CUPR	0.0	1	HYP PROC	0.01	1
HYP REVO	0.0	1	MYU JULA	0.01	1	ORT CRYS	0.01	1
POL STRI	0.0	1	RHA LANU	0.01	4	RHY RUGO	0.01	4
TOM NITE	0.01	6	TOR ARCT	0.01	2	TOR FRAG	0.01	2
TOR TORT	0.0	2	SCHISTID	0.0	1	ENC PROC	0.01	1
ENC ALPI	0.0	1	TOR LATI	0.01	1	FIS OSMU	0.01	2

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

Table 4.15: Average cover values for the undisturbed Cladonia stellaris-Alectoria ochroleuca Plant Community (n=8)

Species	Cover	n	Species	Cover	n	Species	Cover	n
BET GLAN	4.79	8	LIN BORE	0.01	1	MIN ARCT	0.01	2
SIL ACAU	0.60	3	STELL SP	0.01	1	STE LAET	0.50	1
ANT MONO	0.19	1	ARN LOUI	0.01	2	ART ARCT	0.75	5
SOL MULT	0.75	1	CAR MICH	0.49	8	CAR PODO	0.59	1
CAR SCIR	1.51	1	CAR VAGI	0.14	1	EMP NIGR	0.01	3
EQU SCIR	0.19	1	ARC ALPI	0.81	8	CAS TETR	5.68	6
LED DECU	0.25	7	RHO LAPP	0.08	4	VAC ULIG	0.72	8
VAC VITI	0.77	8	GEN GLAU	0.01	1	CAL LAPP	0.01	2
FES ALTA	4.54	1	HIE ALPI	2.58	4	LUZ CONF	0.01	4
LUZ SPIC	0.09	1	HED ALPI	0.01	1	TOF COCC	0.14	2
ZYG ELEG	0.01	1	LYC SELA	0.03	5	EPI LATI	0.01	1
PAP KEEL	0.01	1	PIC GLAU	0.01	1	POL ACUT	0.01	1
OXY DIGY	0.34	1	POL VIVI	0.03	3	ANE PARV	0.01	1
THA ALPI	0.01	2	DRY OCTO	5.78	4	DRY SYLV	4.25	1
POT ELEG	0.01	2	POT FRUT	0.01	1	SAL ALAX	0.01	1
SAL BARR	4.09	1	SAL LANA	0.01	2	SAL PLAN	4.70	2
SAL RETI	4.50	1	PAR KOTZ	0.01	1	SAX HIER	0.01	1
PED CAPI	0.05	3	PED LABR	0.01	2	PED SUDE	0.19	1
AGY RIGI	0.27	7	ALE OCHR	10.84	7	ASA CHRY	1.48	4
CET CUCU	2.55	8	CET ISLA	5.84	6	CET LAEV	12.50	2
CET NIVA	5.90	8	CET RICH	0.63	3	CLA ARBU	0.32	4
CLA MITI	9.51	1	CLA RANG	2.64	7	CLA STEL	21.61	8
CLA AMAU	0.43	3	CLA CARN	0.01	3	CLA CHLO	0.0	3
CLA COCC	0.40	6	CLA GONE	0.01	2	CLA G DI	3.41	1
CLA G GR	0.61	8	CLA META	0.0	2	CLA PHYL	0.0	1
CLA POCI	0.0	4	CLA SUBU	0.01	1	CLA UNCI	0.40	3
CLAD SPP	0.75	5	COR DIVE	0.01	2	DAC ARCT	0.20	7
DAC BERI	0.95	1	PAR SEPA	0.19	2	PAR HYPE	0.01	1
PEL APHT	1.21	1	SPH GLOB	0.80	2	STE ALPI	0.01	1
THA VERM	0.27	4	UMB HYPE	0.36	4	UMB H RA	0.75	1
UMB PROB	0.89	3	CRUSTOSE	8.95	2	SOIL LIC	0.65	1
SAX LICH	3.46	6	RHIZO SP	4.23	5	RHI RIPA	1.36	2
RHI EUPE	1.36	2	RHI INAR	0.01	3	RHI GEOG	0.0	1
LEC DEMI	0.65	2	BUE PAPI	0.0	1	OCH GEMI	0.01	2
HEPATICS	0.10	8	MOSS SPP	0.54	8	AUL TURG	0.01	4
CON TETR	0.0	2	DICRANUM	0.0	2	DIC ELON	0.01	2
HYL SPLE	0.0	1	POL JUNI	2.29	1	PTI CRIS	0.01	2
RHA LANU	0.01	5						

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

islandica. Several vascular plant species such as *Betula glandulosa* (in a prostrate form), *Carex microchaeta* and *Cassiope tetragona* were also noted frequently. The saxicolous lichens on the cobbles included: *Umbilicaria proboscidea, U. hyperborea, Omphalodiscus virginis, O. decussatus* and *O. krascheninnikovii.*

Eight control stands were sampled. Some were located in the Blue Mountain area between R.M.P. 61.9 and R.M.P. 63.5 while others were sampled in the Bolstead Creek area west of Devil's Pass (i.e. R.M.P. 110 to R.M.P. 111.5)(Figure 1.3). A camp yard was the only type of disturbance not sampled in this plant community.

Cladonia stellaris, Cetraria nivalis, Alectoria ochroleuca and miscellaneous moss species cover on all disturbances was less than that of the controls (Appendix VI, I). *Cladonia rangiferina, Rhizocarpon* species, *Cetraria cucullata, C. islandica, C. laevigata, Cassiope tetragona* and *Dryas octopetala* cover was less on four types of disturbances (Table 4.3). All of these species were found frequently on both disturbed and undisturbed sites. *Betula glandulosa* had greater cover on bladed trails and bulldozer tracks but had markedly less than the controls on all other disturbances. The species with higher cover values than those recorded from the control stands varied from one site to the next.

This lichen–dominated community contained disturbances on which vascular plants dominated. These disturbances, with the exception of oil spills, provided habitats capable of supporting a larger number of species than were found in the undisturbed areas (Table 4.5). However, similarity coefficients were lower than those of several other plant communities. The flora of the gravel pit access road most closely resembled that of the undisturbed stands while that of the oil spills had the least similarity (Table 4.4).

Vascular plants have been most successful at colonizing the newly available substrates on several disturbances, despite the fact that lichens dominate in many control stands. After 34–36 years it is difficult to determine if sufficient time has elapsed for lichens to reestablish their dominance or if

the environmental alterations favour the growth of vascular plants. It seems probable that the length of time is most important since many of the common control stand species were present but had little cover on disturbances (Appendix VI, I) Nevertheless, disturbances have promoted diversity in species composition and in structural characteristics.

4.3.1.6 Cushion Plant Tundra

Cushion Plant Tundra was characterized by small patches of vegetation, usually from 30 to 70 cm in diameter, on sites where often more than 50% of the surface area was bare ground. These 'islands' of vegetation were dominated by cushion–forming shrubs such as *Dryas* species and *Silene acaulis*. Cushion Plant Tundra commonly occurred in areas of patterned ground in the following ecosections: Joker Ridge, Blue Mountain, Plains of Abraham Plateau and Bolstead Creek–Devil's Pass. This portion of the study area lies within the unglaciated section of the Mackenzie Mountains.

Cushion Plant Tundra was found most commonly at higher elevations on exposed sites where winter snow cover was thin and discontinuous. It included three distinct plant communities: *Dryas integrifolia-Cetraria tilesii, Dryas integrifolia-Rhizocarpon umbilicatum* and Saxicolous Lichens–*Lecanora epibyron.*

Dryas integrifolia - Cetraria tilesii Community

This plant community occurred on well– to excessively–drained sites in exposed areas on Joker Ridge, Blue Mountain and the Plains of Abraham. Plants were frequently observed without snow cover during the winter or were among the first sites exposed in the spring. The cushion growth form is an adaptation to these conditions (Savile, 1972) and species such as *Dryas integrifolia, Silene acaulis* and *Saxifraga oppositifolia* were frequently found in these areas (Table 4.16). Other species such as *Carex petricosa, C. rupestris* and *C. scirpoidea* were found within the *Dryas* mats and cushions. There was also a diverse lichen flora including such species as *Alectoria ochroleuca, Cetraria tilesii, C. cucullata* and *Thamnolia subuliformis.* Soil lichens included *Cladonia pyxidata, C. pocillum, Pertusaria dactylina, Lecanora epibyron* and *Ochrolecha androgyna. Toninia lobulata* and *Asahinea*

Table 4.16: Average Cover Values for the undisturbed Dryas integrifolia-Cetraria tilesii Plant Community (n=7)

Species	Cover	n	Species	Cover	n	Species	Cover	n
BET GLAN	2.06	4	MEL APET	0.01	1	MIN ARCT	0.21	4
MIN R EL	0.08	3	MIN ROSS	0.19	1	SIL ACAU	1.83	5
STE LAET	0.01	1	ANT DENS	0.21	4	ANT EKMA	0.04	1
ARN ALPI	0.01	1	CHR INTE	0.01	5	SEN ATRO	0.01	1
SEN CYMB	0.06	3	BRA PURP	0.01	3	BRA RICH	0.01	1
DRA CORY	0.04	1	LES ARCT	0.01	2	PAR NUDI	0.05	4
CAREX SP	0.25	1	CAR ATFU	0.01	2	CAR GLAC	2.85	1
CAR MISA	0.01	1	CAR PETR	3.15	7	CAR RUPE	2.03	7
CAR SCIR	1.98	7	KOB SIMP	0.01	2	SCI CAES	0.01	1
EQU VARI	0.19	1	AND POLI	0.08	4	ARC ALPI	0.11	6
CAS TETR	0.80	5	RHO LAPP	1.14	5	VAC ULIG	0.01	2
GEN PROP	0.01	2	ELY INNO	0.15	2	AST UMBE	0.01	1
HED ALPI	0.27	3	HED MACK	0.16	5	OXY JORD	0.07	4
PIN VULG	0.10	4	LLO SERO	0.09	1	TOF COCC	0.05	5
TOF PUSI	0.07	6	ZYG ELEG	0.01	1	PAP KEEL	0.04	1
POL VIVI	0.12	6	WOO GLAB	0.01	2	AND CHAM	0.46	7
ANE PARV	0.01	2	THA ALPI	0.27	7	DRY INTE	12.24	7
POT BIFL	0.01	3	POT FRUT	0.01	5	SAL ARCT	0.16	4
SAL DODG	0.22	2	SAL RETI	0.09	4	PAR PALU	0.01	3
SAX AIZO	0.01	1	SAX OPPO	0.50	7	PED CAPI	0.02	2
PED LABR	0.01	1	PED LANA	0.10	6	PED SUDE	0.10	4
ALE OCHR	1.93	6	ASA CHRY	0.28	3	CET COMM	0.0	1
CET CUCU	1.51	5	CET ERIC	0.14	1	CET ISLA	0.86	6
CET NIVA	0.16	6	CET RICH	0.04	1	CET TILE	3.89	7
CLA ARBU	0.56	2	CLA STEL	0.01	1	CLA POCI	0.01	1
CLA PYXI	1.36	1	CLA UNCI	0.01	1	DAC ARCT	0.16	2
DAC BERI	0.19	2	DAC RAMU	0.14	2	LEC EPIB	1.84	2
OCH ANDR	1.56	1	PER DACT	1.36	1	SOL BISP	0.09	1
THA SUBU	0.62	6	THA VERM	1.66	1	TON LOBU	5.56	1
CRUSTOSE	10.78	2	SOIL LIC	4.94	5	SAX LICH	5.37	3
COLLEMA	0.0	1	VER MURA	1.36	1	POL INTE	0.23	3
POL RUPE	0.68	2	OCHRO SP	0.0	1	MOSS SPP	0.35	6
BRYUM SP	0.0	1	DIT FLEX	0.01	3	DRE REVO	0.0	1
HYPNUM	0.0	1	HYP BAMB	0.01	2	ORT CRYS	0.0	1
POL JUNI	0.0	1	RHY RUGO	0.0	1	TOM NITE	0.0	1
TOR FRAG	0.01	2	TOR TORT	0.0	3	TOR NORV	0.01	1

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

chrysantha were important crustose lichens and the saxicolous lichens included *Polyblastia sendtneri*, *P. integrascens* and *Verrucaria muralis*.

Seven control stands were sampled from the following localities: (1) R.M.P. 56.3, (2) R.M.P. 61.9 to 62.4 near Blue Mountain, (3) R.M.P. 77.2 to R.M.P. 87.5 on the Plains of Abraham and (4)R.M.P. I04.3 in the Bolstead Creek area (Figure 1.3). All disturbance types, with the exception of camp yards, were sampled in this community.

Miscellaneous lichen cover was less than that of the control sites on the road, false start road and gravel pit but greater on all other disturbances (Appendix VI, L and Table 4.3). *Dryas integrifolia* cover was greater on the false start road and bulldozer tracks but lower on the other types of disturbances than in undisturbed areas. *Betula glandulosa*, *Silene acaulis*, *Carex rupestris*, *C. scirpoidea*, *Cetraria cucullata* and *C. tilesii* had less cover on all disturbances with the exception of false start roads. No plant species appeared consistently as recolonizers of the various disturbances in this community but *Salix alaxensis* had notably high cover values, relative to those of the controls, on four of the seven disturbances.

Species richness was lower than that of the control sites on all disturbances in this community (Table 4.5). However, floristic similarities to controls were generally among the highest recorded for this study. The bladed trail plant community was most similar to that of the undisturbed sites while the species composition on the gravel pit access road was most different from the control stands (Table 4.4).

Indications are that the floristic changes have not produced radically different plant communities from those of undisturbed stands. Although richness declined, floristic similarity after 34–36 years was not unduely low. This suggests that little environmental change resulted from the initial disturbances or that local species are well adapted to the colonization of newly available habitats.

<u>Dryas</u> <u>integrifolia</u> - <u>Rhizocarpon</u> <u>umbilicatum</u> Community

This plant community covered extensive areas on the Plains of Abraham and small parts of the Bolstead Creek–Devil's Pass Ecosection. It was restricted to the most exposed portions of the flat–topped plateau where extensive patterned ground occurred and where bedrock was visible. These excessively–drained, calcareous substrates had highly irregular surface microtopography as a result of the presence of frost riven surface material that often measured 50 cm or more in diameter. Vascular plants were restricted to areas in the central portions of the sorted patterned ground where concentrations of fines had accumulated. Cushion–forming plants such as *Dryas integrifolia, Salix dodgeana* and *Saxifraga oppositifolia* (Table 4.17) were able to grow in these areas where moisture was retained for longer periods and snow was less likely to be eroded in winter. Some species that do not normally grow in cushions had also adopted this growth form in this community. These included *Salix arctica* and *S. reticulata*. Many other species were found commonly growing solitarily or within cushions formed by other plants. These included *Draba corymbosa, Parrya nudicaulis*, several Carices, *Polygonum viviparum, Androsace chamaejasme* and *Pedicularis lanata*. The most abundant lichens were saxicolous and *Rhizocarpon umbilicatum* had the greatest cover. Moss species in this plant community (Table 4.17) included: *Hypnum bambergii, Tortella arctica, Tortella tortuosa, Hylocomnium splendens, Ditrichum flexicaule, Campylium stellatum* and *Tomenthypnum nitens.* The soil lichens collected were identified as *Lecanora epibyron, Cladonia pocillum* and *Solarina bispora.*

Eight control stands were sampled within two areas: (1) R.M.P. 80.3 to R.M.P. 84.3 on the Plains of Abraham and (2) R.M.P. 105.9 in the Bolstead Creek area (Figure 1.3). Only false start road and camp yard sites were not sampled in this plant community.

Cover by *Dryas integrifolia* was lower on all disturbance types while road, bladed trail and gravel pit sites had much less cover by *Rhizocarpon umbilicatum* than was found in the control area (Appendix VI, M Table 4.3).

Table 4.17: Average cover values for the undisturbed Dryas integrifolia-Rhizocarpon umbilicatum Plant Community (n=8)

Species	Cover	n	Species	Cover	n	Species	Cover	n
MEL APET	0.01	4	MIN ARCT	0.53	7	MIN R EL	0.09	4
MIN ROSS	0.19	3	SIL ACAU	0.01	4	STELL SP	0.19	3
ANT DENS	0.01	3	ARN ALPI	0.01	1	CHR INTE	0.19	7
SAU ANGU	0.01	1	SEN ATRO	1.51	1	SEN CYMB	0.20	6
BRA PURP	0.14	3	DRA CORY	0.02	6	EUT EDWA	0.01	1
PAR NUDI	0.01	7	SME BORE	0.01	3	CAR ATFU	0.64	2
CAR CAPI	0.34	1	CAR GLAC	0.34	3	CAR MEMB	0.39	5
CAR MISA	0.57	5	CAR PETR	0.01	3	CAR RUPE	0.46	6
CAR SCIR	2.35	2	CAR VAGI	0.13	2	ERI ANGU	1.10	5
ERI CALL	0.80	1	ERI SCHE	0.09	1	KOB MYOS	1.66	1
KOB SIMP	0.05	2	EQU VARI	0.09	1	ARC ALPI	0.01	2
CAS TETR	0.01	7	RHO LAPP	0.01	1	VAC ULIG	8.54	1
ARC LATI	0.04	1	JUN BIGL	0.06	4	JUN ALBE	0.29	1
LUZ NIVA	0.01	1	AST UMBE	0.34	1	PIN VULG	0.01	1
LLO SERO	0.03	4	TOF PUSI	0.53	2	PAP KEEL	0.04	1
PAP RADI	0.14	3	ARM MARI	0.01	1	POL BIST	0.14	1
POL VIVI	0.34	8	AND CHAM	0.11	7	PYROL SP	0.01	1
THA ALPI	0.14	5	DRY INTE	11.36	8	POT BIFL	0.01	1
POT UNIF	0.01	3	SAL ARCT	0.75	5	SAL DODG	0.22	6
SAL POLA	0.01	3	SAL RETI	2.49	5	SAX HIRC	0.01	1
SAX OPPO	0.25	7	PED CAPI	0.08	2	PED LANA	0.88	8
PED ARCT	0.01	2	PED SUDE	0.60	1	TER ALGA	0.40	2
ALE OCHR	0.02	4	CET CUCU	0.84	5	CET ISLA	0.09	3
CET LAEV	0.01	1	CET NIVA	0.14	4	CET PINA	0.01	3
CET TILE	0.28	8	CLA PHYL	0.01	1	CLA POCI	0.01	1
DAC ARCT	0.01	2	DAC BERI	0.01	6	DAC RAMU	0.01	1
EVE PERF	0.01	3	LEC EPIB	1.33	4	POL SEND	2.58	1
SOL BISP	1.00	1	THA SUBU	0.48	8	SOIL LIC	3.23	4
RHI UMBI	12.45	3	HEPATICS	0.01	5	MOSS SPP	2.75	8
BRY TORT	0.0	1	CAM STEL	0.0	2	DIS CAPI	0.0	1
DIS INCL	0.0	1	DIT FLEX	0.0	2	HYL SPLE	0.01	1
HYPNUM	0.0	1	HYP BAMB	0.0	8	MYU JULA	0.0	1
ORT CRYS	0.0	1	TOM NITE	0.0	2	TOR ARCT	0.0	3
TOR FRAG	0.0	1	TOR TORT	0.0	6			

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

Relatively high cover values were noted for various species but none were common to all disturbances. *Salix alaxensis* cover was significantly greater on the road and gravel pit access road sites than in the undisturbed areas. The lower cover of the plant species that were dominant in the control stands, lower species richness and the relatively low similarity coefficients indicate that disturbances in this community have had severe and long-lasting effects.

Saxicolous Lichens - Lecanora epibyron Community

This plant community was restricted to the highest portion of the study area. Areas at elevations above 1,800 m were susceptible to the most rigorous climatic conditions in the study area. Snow free during the winter and excessively drained in the thaw season, these sites experience severe water shortages and desiccating conditions. On the Plains of Abraham, blockfields and sorted patterned ground provide many microsites which was particularly important in affording shelter to vascular plants. Dominant vascular plant species include: *Dryas integrifolia, Carex misandra, C. scirpoidea* and *C. rupestris* as well as the cushion forming *Salix dodgeana* and *Saxifraga oppositifolia*. However, crustose lichens have the greatest cover (Table 4.18). *Lecanora epibyron* was the most abundant lichen identified. However,most other specimens collected were sterile and therefore unidentifiable. These sterile, crustose lichens were found most commonly on the soil surfaces but also covered many rock substrates. Such plants have been noted in other studies and are extremely difficult to identify (Raup 1969, Woo and Zoltai 1977). Identified saxicolous lichens in this plant community (Table 4.18) included: *Lecanora intricata, Rhizocarpon chioneum, Verrucaria muralis* and *Polyblastia hyperborea* The soil lichens included: *Solarina bispora, Baeomyces rufus* and *Evernia perfragilis*.

Three control stands were sampled, all lying between R.M.P. 83.4 and R.M.P. 86.0 on the Plains of Abraham (Figure 1.3). Road, bladed trail and gravel pit disturbances were studied.

Carex petricosa, Carex scirpoidea, Lecanora epibyron and miscellaneous lichen species had markedly less cover on all of the

Table 4.18: Average cover values for the undisturbed Saxicolous Lichen-*Lecanora epibyron* Plant Community (n=3)

Species	Cover	n	Species	Cover	n	Species	Cover	n
MEL APET	0.05	2	MIN ARCT	0.21	3	MIN R EL	0.67	2
MIN ROSS	0.01	1	CHR INTE	0.04	3	SEN ATRO	0.09	1
SEN CYMB	0.01	3	BRA PURP	0.02	2	DRA CORY	0.20	3
PAR NUDI	0.21	3	CAR ATFU	0.01	1	CAR GLAC	0.25	1
CAR MISA	1.18	2	CAR PETR	4.85	1	CAR RUPE	1.80	2
CAR SCIR	2.56	2	ERI ANGU	0.01	1	KOB SIMP	0.01	1
CAS TETR	0.01	1	LLO SERO	0.01	2	TOF PUSI	0.19	1
PAP KEEL	0.06	3	POL VIVI	0.06	3	WOO GLAB	0.01	1
AND CHAM	0.06	3	THA ALPI	0.25	1	DRY INTE	3.81	3
POT VAHL	0.04	1	SAL ALAX	0.01	1	SAL ARBU	0.01	1
SAL ARCT	0.06	3	SAL DODG	0.63	3	SAL POLA	0.01	2
SAL RETI	0.01	1	SAX OPPO	1.26	3	PEDIC SP	0.01	1
PED LANA	0.26	2	PED ARCT	0.01	1	ALE OCHR	0.01	1
CET ISLA	0.01	1	CET NIVA	0.01	1	CET TILE	0.74	3
DAC RAMU	0.01	1	LEC EPIB	23.50	3	SOL BISP	0.14	1
THA SUBU	0.04	3				SAX LICH	29.97	3
POL HYPE	0.0	1	POL GOTH	0.0	1	POL INTE	0.0	2
MOSS SPP	0.13	3	AMBLYSTE	0.0	1	BRA TURG	0.0	1
BRYUM SP	0.0	1	CAT NIGR	0.0	1	DIT FLEX	0.0	1
HYP BAMB	0.01	3	ORT CRYS	0.0	1	TOM NITE	0.0	1
TOR ARCT	0.0	1	TOR TORT	0.0	1			

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

disturbances sampled in this community than on control sites (Appendix VI, N and Table 4.3) and all tended to be restricted to undisturbed areas. Cover by *Dryas integrifolia* was less on the road and gravel pit sites but remained similar to that of the undisturbed areas on the bladed trail. *Salix alaxensis* was the only species to have a significantly higher cover value on a disturbance than on the control sites and this was recorded on the road site only.

Species richness was lower than that of the controls on all disturbances in this community, with the fewest species recorded for oil spills (Table 4.5). Similarity coefficients showed the flora of the bladed trails and gravel pit access roads to be most similar to that of the undisturbed sites while the flora of the oil spills differed to the greatest extent (Table 4.4).

It must be concluded that disturbances in this community have resulted in a simplification of the existing plant community and a reduction in plant species diversity. Both of these changes indicate that disturbances in this plant community create long-term disruptions and that the existing system seems incapable of recovering to a predisturbance state.

4.3.1.7 Crustose Lichen Tundra

Crustose Lichen Tundra occurred in a variety of sites with rock or fine-grained mineral substrates. Lichen cover varied from 100% on some blockfields to 60% on fine-grained mineral substrates. Blockfields and blockslopes in the Blue Mountain and Bolstead Creek-Devil's Pass Ecosections supported this type of tundra. Individual stands varied from a few hundred square meters to 10's of hectares. These areas were within the unglaciated section of the study area and were not common on south-facing slopes. Surfaces were composed primarily of granitic blocks that varied in size from 5 cm to 2 m with an average diameter of 50 cm.

<u>Rhizocarpon</u> <u>inarense</u> - <u>Umbilicaria</u> <u>proboscidea</u> Community

Field identification of crustose and saxicolous lichens was not attempted and therefore it was not possible to subdivide some of the groups included in Table 4.19. However, sufficient information was collected that,

Table 4.19: Average cover values for the undisturbed Rhizocarpon inarense-Umbilicaria proboscidea Plant Community (n=6)

Species	Cover	n	Species	Cover	n	Species	Cover	n
AGY RIGI	0.29	1	ALE OCHR	0.01	3	BAC ALPI	0.01	3
CET TILE	0.01	1	CLA COCC	0.01	3	CLA DEFO	0.01	3
CLA G GR	0.01	3	CLA PLEU	0.06	5	DAC ARCT	0.01	1
DAC RAMU	0.01	4	OMP DECU	1.38	5	OMP KRAS	1.38	5
PAR CENT	0.01	4	PHY CAES	1.38	4	POL SEND	0.0	3
UMB HYPE	5.04	4	UMB PROB	35.50	4			
			RHIZO SP	2.63	4	RHI INAR	37.05	5
LEC PANT	0.0	2	LEC GLAU	0.0	1	LECIDEA	0.01	3
HEPATICS	0.0	3	MOSS SPP	1.38	6	AND RUPE	0.0	5
GRIMMIA	0.0	1	RHA LANU	0.01	6	ORTHOTRI	0.01	1

See Appendix VI for full species names

'0.01' species present with extremely low cover in sample quadrats

'0.0' species present with extremely low cover in sampled stands but outside of the sample quadrats

with the identification of voucher specimens made it possible to describe the plant community in some detail.

Umbilicaria proboscidea and *Rhizocarpon* species were dominant. Species of several other genera of crustose lichens were also found, including: *Lecidea, Parmelia, Polyblastia, Physcia* and *Omphalodiscus.* No vascular plants were found and mosses were restricted to sheltered sites on the sides of and in cracks on the blocks. In this plant community (Table 4.4) six control stands were sampled. All were in the Blue Mountain area (R.M.P. 63.5 to R.M.P. 64.6) and in the Bolstead Creek area (R.M.P. 106.9 to R.M.P. 111.2) (Figure 1.3). Road, false start road, bladed trail and gravel pit disturbances were sampled in this community.

Lecidella stigmatea was the only plant species to have less cover on all disturbances than in the control plant community (Appendix VI, O and Table 4.3). Most of the dominant species in control stands had low cover or were absent from the disturbances. The plants colonizing disturbances varied from one site to the next and most of the species were not found in the undisturbed areas.

It is apparent that plant communities on disturbances were substantially different from those of the controls. This indicates that environmental conditions have been fundamentally changed by the disturbance. Crustose lichens have been noted for their slow growth rates (Hale 1974) and it is expected that these species will take a longer time to recover, if indeed this plant community can ever reestablish itself on the disturbed areas.

Disturbances here have provided environmental conditions less restrictive to vascular plant growth. Furthermore, the relatively simple control plant community has been replaced on disturbances by one which has greater structural and floristic diveristy, particularly in its vascular plant component.

Due to the difficulty in identifying crustose and saxicolous lichen species, these sites may appear to support fewer species than was actually the case. It is interesting to note however, that vascular plants, while essentially absent from the undisturbed plant community, were an important

component of that on the disturbances.

4.3.1.8 Plant Communities Summary

Table 4.3 includes all species, genera or plant groups with cover values differing by 2% or more from the associated control values. A number of taxa which represented major components of the undisturbed plant communities had significantly less cover on disturbed sites (Table 4.3). These included the fruticose *Cladonia* species, *Lecanora epibyron, Rhizocarpon* species, *Cetraria* species, *Stereocaulon paschale, Alectoria ochroleuca, Betula glandulosa, Silene acaulis, Carex misandra, C. petricosa, C. rupestris, C. scipoidea, Arctostaphylos* species, *Cassiope tetragona, Vaccinium uilginosum, Hedysarum alpinum, Dryas integrifolia, Salix barrattiana, S. polaris* and *S. reticulata.* Conversely, several taxa or plant groups had greater cover on many disturbed site types and/or in several areas. These included *Collema* species, *Peltigera* species, *Stereocaulon alpinum, S. saxatile, S. tomentosum,* most *Polytrichum* species, *Minuartia* species, many Composites, *Carex microchaeta, C. membanacea, Trisetum spicatum, Juncus balticus, Epilobium* species, *Salix alaxensis* and *S. glauca.* Many plant species and groups were inconsistent in their responses to disturbance or were not common enough to show trends. In general, taxa that were abundant on control sites had lower cover values on disturbances, while introduced or locally rare plants often became dominant or had greater cover on the disturbed sites than in controls. No non-native species were found colonizing disturbances except where horses had recently used the area. There were no weedy annuals present on disturbances, just native perennials. However, species such as *Salix alaxensis* are common colonizers on natural disturbances and therefore have many of the characteristics of weedy plants. The flora of the control plant communities was substantially different from that of the disturbances and, in some cases, an entirely new assemblage of plants was present.

Bliss (1979) noted that several native vascular plant species were potentially useful for revegetation of disturbances in the Low and High Arctic. Of these, *Arctagrostis latifolia, Calamagrostis canadensis,* and *Deschampsia brevifolia* were also noted in this study. *Arctagrostis latifolia* and *Deschampsia brevifolia* had significantly greater cover on some disturbances. However, all three species on disturbances also had significantly less cover than was found in control stands (Table 4.3). Hernandez (1973) noted a number

of species capable of naturally colonizing disturbances. Three of these also were found to be important components of CANOL disturbance floras. *Poa arctica, Luzula confusa* and *Epilobium angustifolium* all had greater cover on disturbances than in controls (Table 4.3). All of these species were observed in fruit and it seems probable that local seed sources could be harvested or crop areas established to provide seed for revegetation programmes.

Deschampsia brevifolia was an important colonizer on man-induced disturbances in the High Arctic (Babb and Bliss 1974). *Luzula confusa, Dryas integrifolia, Salix arctica* and *Saxifraga oppositifolia* had less cover than on controls. CANOL disturbance data show little consistency among plant communities and disturbance types for these species (Table 4.3). This occurs despite the fact that the floristic and physiognomic characteristics in certain plant communities affected by CANOL disturbances have similarities to High Arctic areas (Brassard, 1972). However, the disturbances discussed by Babb and Bliss (1974) had less recovery time than did CANOL disturbances.

The 'organic crusts' (Raup 1969) on many disturbance substrates often covered substantial areas. It was apparent at the time of sampling that a significant area was occupied by these plants. However, these sterile crusts were not identifiable (Marsh, personal communication, 1980). Woo and Zoltai (1977) have also noted the presence of these crusts in the High Arctic and in the Canadian Rockies (Zoltai, personal communication, 1982). These surfaces can be composed of various species of mosses, liverworts and lichens. However, species of *Polyblastia* (Marsh, personal communication 1980) are thought to be the most important components of the organic crusts sampled on CANOL disturbances.

The highest similarity coefficients were found in association with bulldozer track floras which had values of 74 and 75 in two cases. Bladed trails and bulldozer tracks had the smallest differences and bulldozer tracks were the only type of disturbance with an average of more than 50% of the flora in common with control sites. These represent the only disturbances which initially would have retained, intact, large portions of the existing plant community and in this way could still have substantial portions of the original flora. In the case of bladed trails, Bliss and Wein (1972) described recovery from roots and rhizomes that were left following surface blading. Sprouting from these

contributed to the 30% to 50% cover achieved in 5 years. The lowest similarity coefficients were recorded for gravel pit and false start road sites, which had no species in common with the control stands in the *Rhizocarpon inarense - Umbilicaria proboscidea* community. Disturbances in this community had consistently lower similarity coefficients than were recorded in any other community type. False start roads and gravel pits had resulted in a complete floristic change and roads held only three of a possible 98 species in common with the undisturbed areas (Table 4.5). These crustose lichen communities develop slowly, and based on their similarity coefficients, require much more than 35 years to re-establish a plant community similar to that of the control. In addition, disturbances provide rooting areas and moisture not otherwise available in these areas. Given the degree of substrate alteration, it is doubtful that disturbances other than bladed trails will support plant communities similar to those of the control stands.

The *Salix polaris - Dactylina beringica, Salix barrattiana* - Moss Species and *Salix reticulata - S. lanata* plant communities generally had low similarity coefficients on all disturbances sampled (Table 4.4). The structure of these communities had been altered by the removal of the dominant, shrub component and its subsequent replacement with *Salix alaxensis* and/or *Salix planifolia* which were generally more robust shrubs. Increases in shading and the competition for other resources that would result from these fast growing shrubs would substantially alter the environmental conditions, even on the less disruptive disturbances such as bulldozer tracks.

The *Dryas integrifolia - Cetraria tilesii* and Saxicolous lichens – *Lecanora epibyron* plant communities had the highest average similarity coefficients of all disturbances sampled (Table 4.4). Floristically, these communities tended to be least changed, implying that environmental alterations resulting from disturbances were smaller here than in other plant communities or that the species here were better able to colonize disturbances. The combination of lower species richness, removal of the dominant control species and low floristic similarity to control sites indicate that several plant communities have sustained severe, long lasting, negative impacts. Plant communities affected in this way include: *Carex membranacea-Sphagnum, Hedysarum alpinum*-Moss, *Salix polaris-Dactylina beringica, Dryas integrifolia-Rhizocarpon*

umbilicatum, and Saxicolous lichens–*Lecanora epibyron*. Conversely, there are also cases where, despite cover reductions, the species richness increased and floristic similarity was high. The greater species diveristy and structural complexity on disturbances in these plant communities can be considered to be beneficial and the impacts positive after 34–36 years. Plant communities that provide examples of this include: *Carex* spp.-*Kobresia simpliciuscula*, *Betula glandulosa-Cladonia stellaris*-Moss, *Cladonia stellaris-Alectoria ochroleuca*, and *Rhizocarpon inarense-Umbilicaria proboscidea*.

Considering that recovery on CANOL disturbances has been natural, it is noteworthy that these plant communities have achieved such high cover values. After 34–36 years, cover in Cushion Plant Tundra is an average of 81% of that of the undisturbed plant community whereas in Crustose Lichen Tundra this value is only 30% (Table 4.20). A comparison of disturbances indicates that oil spills have only 31% of the total plant cover of their controls while bulldozer tracks average 87%. Certainly the degree of recovery is closely related to the extent of the original disturbance. However, in some cases little difference in plant cover occurs between fundamentally different types of disturbances. For example, in Erect Deciduous Shrub Tundra there was only a 2% difference in plant cover on gravel pit access roads and on bulldozer tracks (Table 4.20).

In all cases disturbances have greater bare ground than do control stands. After 34–36 years of natural recovery these differences are evident, even on the relatively lightly disturbed sites such as bulldozer tracks. It is also noteworthy that severe initial disturbances such as gravel pits can support a plant cover that is approaching control conditions. In the case of oil spills, they offer little opportunity for plant colonization and consequently support the least plant cover with the greatest reduction from control plant communities. It is evident that rehabilitation is necessary in order to enhance recovery on such long–lasting disturbances.

No disturbance plant community has totally recovered floristically. However, there are several plant communities where similarity coefficients vary little with the type of disturbance. Examples of this (excluding oil spills) include Sedge Meadow Tundra and Cushion Plant Tundra where there was only a 12 and a 10 point spread in values

Table 4.20: Control-corrected bare ground cover (%) on CANOL Project disturbances, N.W.T. in tundra plant communities

Plant Community	Mean Control Values	Road	False Start Road	Bladed Trail	Camp Yard	Bulldozer Track	Gravel Pit	Gravel Pit Access Road	Oil Spill	Mean Cover Difference (all disturbances)
Erect Deciduous Shrub Tundra	8	+52	+45	+44	+10	+18	+60	+20	+94	+43
Decumbent Shrub Tundra	17	+58	+52	+76		+28	+70	+42	+49	+47
Sedge Meadow Tundra	14	+46		+ 1		+32	+26		+58	+33
Lichen Heath Tundra	8	+56		+22			+72		+74	+56
Fruticose Lichen Tundra	3	+53	+75	+72		+ 3	+79	+25		+51
Cushion Plant Tundra	57	+29		+14			+28	+ 5		+19
Crustose Lichen Tundra	6	+75					+66			+70
Mean Cover Difference (all communities)		+53	+57	+38	+10	+13	+57	+23	+69	

respectively (Table 4.21). It is also evident that Decumbent Shrub Tundra and Lichen Heath Tundra show a high degree of variability in the disturbance similarity coefficients. In this case, disturbance type seems to be a determining factor in their long-term floristic evolution. It is inaccurate to state that the slow rate of recovery or colonization displayed by most non-crustose lichen species found in control stands is a factor since Cushion Plant Tundra and Lichen Heath Tundra both have a significant number of lichen species. Nor is it necessarily a consequence of substrate characteristics since Cushion Plant Tundra and Decumbent Shrub Tundra can be found on similar soil types. It does not appear to be a consequence of the ability of the individual control stand plants to colonize adjacent disturbances since mean similarity coefficients indicate that Sedge Meadow Tundra and Cushion Plant Tundra (the 2 communities with little intradisturbance variability) have the highest and one of the lowest degrees of floristic difference from their control stands respectively. Given the variability noted above, it is evident that there is probably more than one controlling factor and that the dominant one changes with the plant community. This seems to be the most satisfactory answer since these comparisons are made among highly variable plant communities whose very structure reflects differences in ecologically limiting factors.

Studies on oil spills have noted plant recovery after short time intervals (e.g. 0-5 years) (MacKay et. al. 1979, Hutchinson and Hellebust 1978, Bliss and Wein 1972, Wein and Bliss 1973, Babb and Bliss 1974, Walker et. al. 1978, McKendrick and Mitchell 1978). Results from CANOL oil spill studies confirm that recovery is occurring but more slowly than the literature suggests, perhaps as a result of the recontamination mentioned by MacKay and Deneke (1979) or the delay in response noted by McCown and others (1972) but not evident with short term studies. Given the low plant cover on CANOL oil spills, it seems reasonable to assume that these sites remain hostile as a result of their extreme aridity, as is suggested by the results of studies by Bliss and Wein (1972) or because they remain phytotoxic as is suggested by the lack of degradation noted in Section 3.3.2.

Table 4.21: Floristic similarity coefficients comparing control and CANOL Project disturbance plant communities, N.W.T.

Disturbance Type / Plant Community	Road	False Start Road	Bladed Trail	Camp Yard	Bulldozer Track	Gravel Pit	Gravel Pit Access Road	Oil Spill	Mean Similarity Coefficient (all disturbances)
Erect Deciduous Shrub Tundra	44	60	51	28	59	51	49	40	48
Decumbent Shrub Tundra	57	37	60		63	54	53	29	50
Sedge Meadow Tundra	35		47		44	35		19	36
Lichen Heath Tundra	26		60			38			22
Fruticose Lichen Tundra	43	40	46		59	49	57		49
Cushion Plant Tundra	49		59			56	58		56
Crustose Lichen Tundra	26					34			30
Mean Similarity Coefficient (all communities)	40	46	54	28	56	45	54	28	

4.3.2 Shrub Ages

The 172 shrubs collected and aged included the following species:

1. *Salix alaxensis* – 120 specimens
2. *Salix planifolia* – 28 specimens
3. *Salix reticulata* – 4 specimens
4. *Salix arctica* – 3 specimens
5. *Salix arbusculoides* – 2 specimens
6. *Salix lanata* – 1 specimen
7. *Salix glauca* – 1 specimen
8. *Betula glandulosa* – 13 specimens

Several specimens taken from disturbances were much older than the CANOL Project. A *Betula glandulosa* shrub dating from 1929 was found on a road site, a *Salix planifolia* from 1936 on a bladed trail, a *Betula glandulosa* from 1941 on a bulldozer track, two *Salix alaxensis* from 1932 and 1940 in gravel pits and one *S. arctica* from 1935 on an oil spill. *Salix alaxensis* was seldom a major component in control stands but the other species sampled were frequently dominant in undisturbed areas. These plants were probably uprooted or broken off and then inadvertently transplanted onto the disturbed sites, perhaps as part of the fill used during construction (Porsild 1950:34). This is supported by the fact that 4 of the 5 cases occurred in Erect Deciduous Shrub Tundra (Table 4.22). An alternative hypothesis is that previously existing shrubs on the site were not killed. The shrub from the oil spill site was found on a raised, seemingly uncontaminated, portion of the area affected. These individuals have been removed from the data set since this study is concerned with the species that have colonized disturbed areas by seed dispersal over the past 35 years. All five of the shrub samples taken from control sites predated 1927, the oldest being a 168–year–old *Salix alaxensis* specimen. Although the sample size was small, it is interesting to note that none of the control site shrubs post–dated the CANOL Project. Adkins (personal communication September 1982) reported that shrubs as old as 400 years have been sampled in the Macmillan Pass area. Indications are that little shrub seedling survival occurs in undisturbed areas. Natural and man–induced disturbances provide the necessary conditions for successful shrub seed germination and growth.

The selection of the largest and presumably oldest shrubs for sampling, has produced a skewed distribution of shrub ages. However, this does not preclude more recent shrub colonization. The main purpose of the sampling was to determine the time at which shrubs were first able to become established in disturbed areas.

Shrub origin dates on disturbances generally showed little variation (Table 4.22) [11]. Average ages on road and oil spill sites (i.e. dating from 1958 and 1964 respectively) were younger than those found on other types of disturbances (i.e. dating from 1951 to 1954) except in Fruticose Lichen Tundra. When they were present, the average age of shrubs on oil spills was ten years younger than the other disturbances, however, these disturbances generally lacked any shrub cover except on slightly elevated sites that were presumably less affected by the oil. This suggested that even after 34–36 years this environment remains hostile for these woody plants.

Shrubs on disturbances caused by the deposition of fill were an average of four years younger than those on excavation types. The oldest mean dates of shrub recolonization were found in gravel pits excavated in Sedge Meadow Tundra and on false start roads located in Erect Deciduous Shrub Tundra (Table 4.22). Excluding the oil spill shrub data, all mean shrub ages fall within the 12 year period extending from 1948 to 1960, indicating that this period was perhaps more suited to shrub colonization. It was during this time interval that salvage operations were conducted (Section 2.3.7, Table 2.5). It seems probable that some redisturbance of the road occurred, however no grading was done. No age differences were noted between road shoulder and road centre locations. Furthermore, no damage to shrubs was noted for those pre-dating the salvage. It was therefore concluded that the shrub colonization dates from the road were not affected by salvage operations that would have removed shrubs.

Willow species are known for their ability to reproduce vegetatively. Cuttings have been used in revegetation studies (Brown and Berg 1980; Johnson 1981; Younkin 1976) but with variable success. In this study, marker pegs, cut from live shrubs, stripped of leaves and placed in the ground to locate plant community sample points, were

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[11] Forb Meadow Tundra has not previously been discussed (Section 1.7) and included forb-dominated plant communities. Collectively, forbs dominated but, on an individual species basis, sedges and mosses were more common. Forb species included *Petasites hyperborea*, *Thalictrum alpinum*, *Artemisia arctica*, *Pedicularis* species, *Polygonum viviparum*, *Geum rossii*, and *Rhodiola integrifolia* plus numerous others.

Table 4.22: Shrub origin dates in control and CANOL Project disturbance plant communities, N.W.T.

Plant Community	Control	Road	False Start Road	Bladed Trail	Camp Yard	Bulldozer Track	Gravel Pit	Gravel Pit Access Road	Oil Spill	All Fill Types	All Excavation Types
Erect Deciduous Shrub Tundra	1902	1955[a]	1948	1953[b]	1951	1954[c]	1950[d]	1951		1953	1952
n	2	7	1	15	1	4	17	2		10	33
Decumbent Shrub Tundra	1867	1960	1954	1953		1954	1953	1954	1963	1953	1952
n	1	15	3	5		2	11	5	3	23	16
Sedge Meadow Tundra		1954					1948			1954	1948
n		4					2			4	2
Lichen Heath Tundra	1813	1959		1952			1952		1964	1959	1952
n	1	5		4			2		1	5	6
Fruticose Lichen Heath Tundra		1952	1954	1950		1950	1954	1954		1953	1953
n		4	1	3		1	5	2		7	8
Cushion Plant Tundra	1854	1959		1956			1954	1950		1957	1955
n	1	6		7			5	2		8	12
Crustose Lichen Tundra		1958	1957				1952[e]			1958	1955
n		6	1				2			7	2
Forb Meadow Tundra		1960		1957		1954	1952			1960	1954
n		3		1		1	1			3	2
Mean Date of Origin[f]	1868	1958	1954	1953	1951	1954	1952	1953	1964	1956	1952
Standard Deviation	41.2	4.6	4.2	4.8	NA	5.0	4.7	4.4	5.3	4.9	4.7
Sample Size	5	50	7	35	1	8	45	11	4	68	81

a one shrub dating from 1929 excluded
b one shrub dating from 1936 excluded
c one shrub dating from 1941 excluded
d one shrub dating from 1940 excluded
e one shrub dating from 1932 excluded
f shrubs originating prior to 1943 on disturbances are not included

observed sprouting within 1 to 2 years time. Sprouting of *Salix alaxensis* was noted on bladed trails, bulldozer tracks, gravel pits, oil spills and controls. Not all shrubs were re-examined, but sprouting markers were found on both 1977 and 1978 sites. These observations, although limited, are supported by findings in Alaska where unrooted *Salix alaxensis* had greater survival success than did rooted material (Johnson 1981). It should also be noted that the lack of leaves on the marker pegs may have reduced water loss at the critical time when roots had not yet developed. Further work is needed in this area, particularly in reference to oil spills where cuttings may be able to root below the maximum depth of oil penetration and therefore aid in revegetation programmes.

In summary, shrubs colonized most types of disturbances within the 12 year period beginning three years after abandonment. Oil spills were the exception since shrubs on these disturbances dated from 1963-1964. A few shrubs were either transported onto disturbances or survived the impact of these disturbances since some specimens pre-dated the CANOL Project construction period.

4.3.3 Above-Ground Phytomass

Detailed above-ground phytomass (phytomass) data are presented in Appendix V and a summary of these is presented in Table 4.23. Phytomass values from each of the seven physiognomically defined plant communities are included, with both control-corrected and uncorrected values. The mean above-ground phytomass for all disturbances within each plant community was expressed as a percentage of the mean control value in order to determine the mean per cent reduction from the control values.

The various tundra plant communities differed greatly in their above-ground phytomass with mean values ranging from 74 g/m^2 in the Crustose Lichen Tundra to 3,883 g/m^2 in Erect Deciduous Shrub Tundra (Table 4.23). The average above-ground phytomass on control sites was higher than the mean value recorded for any of the disturbance types. Bulldozer track disturbances had the greatest total phytomass, equivalent to 73% of the control mean, while gravel pits had the smallest accumulations, with values equivalent to 8% of the control mean.

Table 4.23: Summary of mean control-corrected (cc) and uncorrected (u) above-ground phytomass (standing crop)(gm^{-2}) of control and CANOL Project disturbance plant communities, N.W.T.

Plant Community		Road	False Start Road	Bladed Trail	Camp Yard	Bulldozer Tracks	Gravel Pit	Gravel Pit Access Road	Oil Spill	Mean % Reduction From Control Values	Mean Control Values
Erect Deciduous Shrub Tundra	cc	-4,150	-2,245	-3,227	-2,729	-3,051	-3,165	-1,265	-5,627	81	3,883
	u	149	215	258	914	1,223	114	432	4		
Decumbent Shrub Tundra	cc	-808	-351	-894		-879	-816	-808	-1,161	99	927
	u	156	38	96		366	61	365	76		
Sedge Meadow Tundra	cc	-1,236		-1,316		-971	-674		-926	61	1,668
	u	184		1,316		2,139	459		46		
Lichen Heath Tundra	cc	-1,596		-1,500			-1,878		-1,908	90	1,596
	u	312		409			31		1		
Fruticose Lichen Tundra	cc	-876	-839	-1,353		-439	-1,586	-2,024		72	1,649
	u	296	92	447		1,361	63	549			
Cushion Plant Tundra	cc	-57		-56			-80	+6		59	78
	u	25		24			1	76			
Crustose Lichen Tundra	cc	-46		-92			-27			74	74
	u	28		1			28				

The minimum percentage of total phytomass represented by shrub species[12] was higher on the road, false start road, gravel pit and gravel pit access road sites than in the control areas (Appendix V, Table A). This was somewhat surprising since the mean date of origin for roads and false start roads was more recent than that of most other disturbances. The time during which phytomass accumulation has occurred would therefore have been less than that of most other disturbance types. Conditions on roads in particular must be highly conducive to the growth of shrub species that are able to colonize this disturbance since the mean date of shrub origin was at least 4 years later than that of all other disturbances, with the exception of oil spills.

The sparse plant cover of the Cushion Plant Tundra showed the least difference in phytomass as a result of any disturbance and was the only type of plant community to have a disturbance supporting a greater phytomass than its control stands (Table 4.23). It would appear that the new environmental conditions created by disturbances in this community were least limiting relative to conditions in associated, undisturbed areas. In Lichen Heath Tundra, the phytomass on disturbances was 10% of the control levels, indicating that environmental alterations created severely limiting conditions on disturbances which inhibited their ability to produce and/or retain phytomass even after 34–6 yrs. The undisturbed, Erect Deciduous Shrub Tundra supported a phytomass two to 50 times greater than that of the other communities and in absolute terms it experienced by far the greatest loss of phytomass on all disturbances, with the exception of gravel pit access roads. Phytomass reductions were great due to the large phytomass in the Erect Deciduous Shrub Tundra. However, a comparison of disturbances indicates that 13 cases occurred where the phytomass supported on disturbances in other plant communities was greater than that on similar disturbances in Erect Deciduous Shrub Tundra. Not only did disturbances in the areas with higher phytomass cause the greatest reduction in available phytomass but also, the new disturbance systems were more restrictive to phytomass accumulation (plant growth) than in other communities (i.e. cf. bladed trails in Sedge Meadow Tundra, Lichen Heath Tundra and Fruticose Lichen Tundra – Table 4.23). Disturbances in these cases caused greater changes initially and also had a slower recovery rate. It is also noteworthy that the mean shrub colonization dates for

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[12]These are minimum values as some of the smaller samples were left undifferentiated (Appendix V)

most disturbances in Erect Deciduous Shrub Tundra were older than those recorded in most other plant communities (Table 4.22). Despite longer periods with shrub cover, the phytomass accumulation rates must have been lower and since herbaceous plants are generally the pioneer species it follows that shrubs would only make a significant contribution after the establishment of herbs. A final point is that disturbances in Sedge Meadow Tundra had higher phytomass values than did similar disturbances in other plant communities with the exception of oil spills in Decumbent Shrub Tundra (Table 4.23).

Bulldozer tracks in the Sedge Meadow Tundra possessed the largest phytomass of any disturbance while oil spills and gravel pits in Lichen Heath and Cushion Plant Tundra respectively had the lowest values (Table 4.23) . Lichen Heath and Decumbent Shrub Tundra showed the greatest overall reductions in standing-crop while Cushion Plant and Sedge Meadow Tundra had the smallest changes. Woody and fruticose lichen-dominated tundra therefore displayed greater differences in phytomass than did herbaceous, crustose lichen and sparsely covered plant community types (Table 4.23). This is to be expected since a higher proportion of the phytomass is contained in the woody plants. Loré (1977) reported similar results from 50-year-old cart tracks on the Burwash Uplands. He noted that annual above-ground dry matter was less than 50% of that of disturbed sites in Sedge tussock and Sedge-heath Tundra.

Oil spills supported the lowest phytomass in three of the four plant communities in which they were sampled and showed the greatest overall difference from control stands (Table 4.23). After 35 years, oil spills remain the most limiting environment for plant production. McCown and others (1972) reported that 3-year-old crude oil spills in wet-grass-sedge tundra had a maximum of 97% phytomass reduction. This was identical to the 97% reduction noted in Sedge Meadow Tundra in this study, with the important difference that the CANOL spills were more than 10 times older. This is a significant distinction since many short-term studies in Sedge Meadow Tundra indicate that long-term recovery should be much greater than that observed on CANOL spills. Wein and Bliss (1973) noted 20-50% recovery by the second growing season while Hutchinson and Hellebust (1978) found cover values on 2-year-old crude oil spills that were 25% of the control values. Walker and others (1978) found similar results in wet sedge meadows. In light of the results from the CANOL studies, these observations are

difficult to explain. The only other long-term study is that of Lawson and others (1978) where 28-year-old diesel fuel spills had 55 to 15% plant cover. However, it should be noted that refined fuel was generally more destructive than crude oil when spilled (Hutchinson and Freedman; McCown et. al. 1973). It may be that short term recovery is nullified by physical processes that recontaminate growing plants with the remaining oil residue. In sedge meadows, a high water table reduces contamination of the rooting zone. However, in a particularly dry year, oil may penetrate to this area and eventually kill the plants. In plant communities other than Sedge Meadow Tundra the long-term effects of oil spills were more severe with greater phytomass reductions.

Phytomass production on false start roads varied considerably but the overall difference from the controls was smaller than that recorded for any other disturbance type. Phytomass on these sites was therefore most similar to that of the associated control stands.

Total phytomass recorded on any one disturbance never exceeded the mean control value (Appendix V, Table A). The relatively high percentage of woody phytomass on the road, false start road, gravel pit and gravel pit access road sites, in comparison to the average control levels (Appendix V), was due primarily to the presence of *Salix* species. Lack of competition from other plants and the adaptability of many members of this genus enabled these shrubs to utilize habitats where other plants were limited. Numerous cases were noted where the ground immediately below the shrubs had thick accumulations of leaf and other types of litter. In these cases, higher moss and forb cover was also found. It seems probable that the shelter from wind afforded by the shrubs reduced the loss of leaf litter and enhanced snow accumulation while the shade reduced surface moisture losses. The resulting habitat was less hostile and mosses and forbs were able to colonize these microsites more successfully. The shrubs would give little competition for moisture since they are generally more deeply rooted than are herbaceous plants.

4.3.4 Above-Ground Phytomass Summary

Above–ground phytomass was less than that of the control sites on all disturbances in all plant communities with the exception of a gravel pit access road in the Cushion Plant Tundra. Mean per cent differences from control stands were lowest where control phytomass was small. Oil spills had the greatest differences in phytomass while on the false start roads it was the most similar to that of the controls. Disturbances through plant communities with a high amount of phytomass seldom have the highest accumulations after 34–36 years. The herbaceous dominated, Sedge Meadow Tundra had the greatest phytomass on all disturbances with the exception of oil spills. These points indicate that initial disturbances and long–term phytomass responses were most severe in the structurally complex, shrub–dominated plant communities. This is probably due to the fact that woody species are generally slow growing and at first will cover much less area than will herbaceous plants. In time, this situation could be reversed. After 34–36 years, disturbances support 10 to 41% of the control plant community phytomass. This was surprising since the control values were the product of much longer periods of accumulation and currently higher plant cover values. For example, shrubs in Cushion Plant Tundra indicate that this community was at least 124 years old. The average phytomass on disturbances was 41% of that of the control in that community after only 35 years.

4.4 Conclusions

Woody plants colonized most disturbances within nine years of abandonment. Roads and oil spills were an exception to this, with an average of 13 and 19 years respectively passing prior to establishment of the first shrubs. The shrub species most commonly found in disturbed areas were members of the genus *Salix,* though *Betula glandulosa* was also common on a few sites.

Above–ground phytomass was less than that of controls on all disturbances. Oil spills and gravel pits had the smallest phytomass while bulldozer tracks had the largest accumulations. When compared to the associated control values, the phytomass of the oil spill sites showed the greatest reduction and the phytomass on the false start road, the least. Despite this, it is noteworthy that after 34–36 years, phytomass was on average between 10% and 40% of control values. In some cases, even disturbances resulting in

total removal of predisturbance plant biomass now have accumulated 35% to 40% of control values. This represents excellent recovery, particularly since the rate of increase would be slow for several years (e.g. for the first 9 to 13 years for shrub species). However, this lag is a concern since the extent of surface erosion and thermokarst can be related to the surface plant cover as well as an host of ecological consequences (e.g. wildlife habitat, soil nutrients, etc.).

Within each of the fifteen floristically defined plant communities, responses to disturbances were often unique. It was generally found that, when lichens were common in the control, they were absent from, or much reduced on the disturbances. Several groups of plants, and most commonly the dominant species of the undisturbed stands, had notably less cover. Higher cover values were noted for approximately the same number of taxa as had lower values. The cover differences relative to controls often varied with the type of disturbance and the plant community affected (Table 4.5). Consequently, it is difficult to make generalizations regarding the suitablility of a particular species for revegetation.

However, a number of plant species consistently demonstrated an ability to disperse from areas outside of those directly affected by the CANOL Project and to establish themselves successfully on most types of disturbances (Table 4.24). Several of these species have been noted in other studies for their potential for use in revegetation programmes. Few studies have reported on colonizing bryophytes. None of the bryophytes noted on disturbances by Johnson, Murray and Murray (1978) were common on CANOL disturbances. *Polytrichum juniperinum* was noted recolonizing after a fire in the Tuktoyaktuk region. In Alaska, *Polytrichum* sp. was one of the earliest colonizers on natural tundra disturbances (Peterson and Billings, 1978). Few of the lichens included in Table 4.24 have been noted in the literature as disturbance colonizers. Peterson and Billings (1978) noted that *Stereocaulon* sp. and *Cetratia* spp. were important components of the plant cover on natural disturbances in the Alaskan Arctic coastal plain. *Stereocaulon* species have also been described as increasing in cover in areas of heavy reindeer grazing in Finland (Kallio et. al. 1969; Pulliainen 1971). In these areas, trampling and grazing can substantially alter the plant communities. Several of the vascular plant species noted in this study have been reported as successful colonizers of natural and man-induced

Table 4.24: Plant species with demonstrated ability for long-distance dispersal and colonization success on CANOL Project disturbances, N.W.T.

LICHENS	MOSSES	VASCULAR PLANTS	
Cladonia macrophylla	*Polytrichum* sp.	*Calamagrostis canadensis**	*Minuartia rubella*
C. pyxidata	*P. hyperboreum**	*Carex aquatilis**	*Poa alpigena**
C. subulata	*P. juniperinum**	*C. lugens**	*P. pratensis**
Collema sp.	*P. piliferum**	*C. membranacea**	*Salix alaxensis**
Lecidella stigmatea	*P. polydactyla**	*C. microchaeta**	*S. arbusculoides**
Pannaria pezizoides	*P. strictum**	*C. podocarpa**	*S. glauca**
*Peltigera aphthosa**		*Dryas octopetala**	*S. lanata**
*P. canina**		*Empetrum nigrum*	*S. planifolia**
*P. polydactyla**		*Epilobium anagallidifolium*	*Trisetum spicatum**
*P. rifescens**		*E. angustifolium**	*Veronica wormskjoldii*
Rinodina roscida		*E. latifolium**	
*Stereocaulon alpinum**		*Hedysarum mackenzii**	
*S. paschale**		*Hierochloe alpina**	
*S. saxatile**		*Juncus balticus**	
*S. tomentosum**		*Linnaea borealis*	
Toninia lobulata		*Minuartia macrocarpa*	

* Species consistently forming a high proportion of standing crop and cover on disturbances

disturbances in other studies. These included *Carex aquatilis* (Bliss and Wein 1972; Hernandez 1973; Johnson et. al. 1978; Lore 1977), *Empetrum nigrum* (Johnson 1980; Wein and Bliss 1973); *Epilobium* species (Hernandez 1973; Johnson 1980), *Calamagrostis canadensis* (Bliss and Wein 1972; Hernandez 1973; Johnson 1980; Johnson and VanCleve 1976; Lambert 1972; Peterson and Billings 1978; Younkin 1976), *Poa* species (Bliss and Wein 1972; Hill, Freedman and Svoboda 1980; Johnson 1980; Johnson et. al. 1978; Peterson and Billings 1978; Younkin 1976; Yurtsev and Korobkov 1979), *Dryas* species (Babb 1973; Hill, Freedman and Svoboda 1980; Johnson 1980) and *Salix* species (Bliss and Wein 1972; Druzhinina and Zarkova 1979; Hill, Freedman and Svoboda 1980; Johnson 1980; Johnson 1981; Johnson et. al. 1966; Johnson et.al. 1978; Lambert 1972; Peterson and Billings 1978). Not all the studies have been of long-term disturbances. However, it is apparent that these species or genera are successful colonizers of disturbances on a circumpolar basis.

Long distance dispersal is an important component of vegetation recovery in most ecosections. It would therefore be difficult to determine what native species are best adapted to disturbed environments by selecting only from promising local species on undisturbed areas The species that consistently demonstrate the capability for colonization and long-distance dispersal have been identified (Table 4.24) and should be considered as preadapted for similar northern environments. Furthermore, several of these species consistently form a high proportion of disturbance above-ground phytomass and cover. These species should therefore be carefully considered since they appear to be ideally suited for revegetation programmes in northern reclamation projects.

Those vascular plants with the ability to bind soil and reduce soil erosion would be especially important for reclamation programmes. Plants particularly suited for this purpose would include *Calamagrostis canadensis*, *Carex* species, *Hierochloe alpina*, *Poa* species and *Trisetum spicatum*, all of which are graminoids capable of rapid sexual and vegetative propogation (Table 4.24). In addition, the *Salix* species have the ability to enhance soil moisture on disturbances since they trap drifting snow and shade the soil surface. These species often are also desirable forage for resident herbivores.

Species composition was simplified relative to control stands, on disturbances in the *Dryas integrifolia*-dominated plant communities. Oil spills and roads most often had relatively low species richness. Definite assemblages of plants were found on each disturbance type, though these varied as the associated control plant communities changed. All CANOL disturbances were small in area and therefore the transport distance was not significantly different among the 8 types of disturbances sampled. Assuming that rates of migration into disturbed areas at a given site were equal, those disturbances with high species diversity would appear to have created environments conducive to growth and reproduction of a wide variety of plants. Low species diversity could reflect a relatively severe environment where only the hardiest species are able to survive or a habitat especially suited to only a few species.

Considering all of the parameters discussed above, after 34-36 years, plant communities on oil spills, roads and gravel pits showed the greatest degree of difference from while plant communities on bulldozer tracks were most similar to the undisturbed stands. However, it is evident that all disturbances have produced changes and in some cases it is difficult to conclude that a predisturbance state can be reestablished, even within an extremely long time frame. The environmental conditions that led to the formation of the control plant communities have been changed by the disturbances and it is reasonable to assume that successional processes will lead to the establishment of stable plant communities that are substantially different from those that were undisturbed. It is also evident in cases where the initial disturbance was slight (i.e. bulldozer track) or where disturbances produced environmental alterations not substantially different from control conditions (i.e. in Cushion Plant Tundra) that the product of long-term evolution will result in plant communities that are more similar to controls than at present.

Disturbances with their own distinctive plant communities are generally linear disruptions in an otherwise gradually changing landscape composed of a mosaic of plant communities. In extensive, homogeneous plant communities, the abrupt change in species composition, plant cover, phytomass and structure provide variability that otherwise occurs only along natural disturbances. In the region containing the stable, homogeneous plant community the relatively rapidly changing disturbance plant community can be a

positive ecosystem asset. It is here that new species can become established and aid in diversifying the region's ecological characteristics. Although examples of ecosystem simplification occur (e.g. CANOL oil spills), there are also cases of ecological diversification. The removal or partial destruction of a plant community will result in long-term changes that may be positive or negative ecosystem alterations, varying in degree, but essentially permanent.

Finally, there is no evidence to suggest that the plant communities on disturbances are presently stable. However, it appears that the rate of change varies with the type of disturbance and the plant community in which it occurred. In any case, it is difficult to predict the point at which structural and floristic stability will be reached and the time required to achieve this result.

5. WILDLIFE UTILIZATION OF CANOL DISTURBANCES

5.1 Introduction

This section deals with that portion of the ecosystem that Dansereau (1971) has referred to as the 'zootrophic' level. Discussion will concentrate on resident species of birds and mammals. The 'lower' orders of animals were not studied. The purpose of these studies was to determine what effects the alterations of soils/substrates and plant communities have had upon resident wildlife. Two purposes of this study were:

1. To identify the species using the disturbances and
2. To ascertain whether CANOL disturbances have affected the amount of wildlife use in these areas.

These studies considered both herbivore and carnivore trophic levels. The small mammals and ptarmigan studies are primary consumers as are the larger ungulates (e.g. moose, sheep, caribou) while foxes and wolves are secondary consumers, preying upon other species. Grizzly bears are omnivores and therefore can be placed at both levels of the food chain. The studies of resident wildlife were designed to complete the analysis of disturbed ecosystems which would then include key components of the abiotic controls, primary producers and first and second order consumers.

In contrast to plants, animals can choose the areas they wish to use for various purposes. By comparing the use of several areas by a particular species it is possible to determine which are prefered for particular activities by that animal. Assessment of use was made directly, through censuses and direct observation, and indirectly by noting evidence of browse or the presence of pellet groupings.

Nomenclature in this chapter follows the taxonomic treatment of Banfield(1977) and Youngman(1975). Final species identification of small mammals was made by Stephen Beare, Department of Zoology, The University of Alberta, on the basis of dentition and pelage.

5.2 Literature Review

Information pertaining to two wildlife inventories is available for the Northwest Territories section of the CANOL Project. The first inventory, in 1944, included reports on mammals and birds (Rand 1945a and 1946 respectively). The second included only the large mammals (Gill 1978). These reports provide inventories of species present in the area but do not discuss the effect of the CANOL Project on this resident wildlife.

Little information is available in the literature regarding the long-term effects of disturbances in their abandoned state on northern wildlife. Pruitt (1970) makes reference to the fact that *Microtus oeconomius* colonized areas on the North Slope of Alaska affected by bulldozer tracks and bladed trails. However, Douglass(1977) and Riewe(1979:63-65), conducted detailed studies on small mammal use of disturbances and concluded that the habitat resulting from seismic line construction was preferred by meadow voles (*Microtus pennsylvanicus*) but not by boreal red-backed voles (*Clethrionomys rutilus*). Both studies were completed in forested sites, with Douglass studying a winter road and Riewe working on bladed trails and seismic lines. Riewe's (1979) studies of disturbances one to six years old, showed an overall decline in small mammal numbers. Lore (1977), working on 50-year-old cart tracks, determined that large and small mammals prefer disturbed habitats. Small mammal trapping success was 8 and 5 times greater than that of controls for *Microtus oeconomus* and *Sorex cinereus* respectively while *Clethrionomys rutilis* was taken only on disturbances. Caribou (*Rangifer tarandus osborni*) preferred the browse available on the trail to that of the undisturbed areas while Ptarmigan utilized the disturbance in greater numbers than on the control sites throughout the year.

5.3 Methods

The data presented are derived primarily from the 1979 summer, and to a lesser extent, from the winter field seasons of 1978 and 1979. Observational data were collected throughout the study. In addition to this, small mammal trapping and wildlife sign transect studies were completed in areas that had previously been sampled for vegetation and substrate information.

5.3.1 Field Methods

5.3.1.1 Small mammal traplines

Small mammal traplines were established and maintained over three trap-nights at each site. It was not possible to fit a large number of traps into the more localized disturbances such as oil spills and bulldozer tracks. Many of the disturbances studied were linear and did not cover a broad area. Consequently it was decided to use a trapline rather than to set traps in a grid pattern. Each trapline consisted of 14 Woodstream Museum Special snap traps baited with a mixture of peanut butter, rolled oats and bacon fat. Lines were limited to 14 traps for two reasons. 1) many of the disturbances covered relatively small areas and could not accomodate large numbers of traps. 2) camp was moved every three days, which involved backpacking all food and equipment for distances of up to 35 km. Consequently, it was necessary to keep the amount of equipment to a minimum. One hundred and thirty traps were carried, weighing 6 kg. With these traps, nine lines could be run simultaneously. All lines were placed through the centres of disturbances in order to minimize the edge effect and each was checked twice daily, in early morning and late evening. Trapped animals were sexed, measured and weighed and the skulls and skins were retained for final identification.

5.3.1.2 Wildlife sign transects

A belt transect 2 m wide and 65 m long was established at each site. Within this area, droppings (i.e. individual scats or pellet groups), tracks and other signs were identified and counted. In all cases, the transect ran through the centre of the area under study and included as many microsites as was practical while still remaining representative of the general area. Usually, the belt transect parallelled the trapline and included the vegetation quadrats.

A log of animal sitings was maintained during the summer of 1979 and in the winter field seasons. In this, species, sex, number of animals and location were recorded with comments on behaviour and other points of interest. Less detailed observations were made in the 1977 and 1978 summer field seasons.

All abandoned pipe sections, buildings and bridges were inspected for signs of avian and/or mammal use. When wildlife use was noted in a particular area (i.e. ground

squirrel burrows in gravel pit spoil heaps) , spot observations were recorded.

5.4 Results

5.4.1 Small Mammal Traplines

A total of 121 traplines were run with 42 trap-nights at each. [13]. Twenty-eight traplines were located on control sites. Twenty-nine small mammals and thirteen birds were taken over 5,061 trap-nights, giving a success ratio of 0.83 animals (including birds) or 0.57 small mammals in 100 trap-nights. Table 5.1 illustrates that roads and bladed trails had success rates equal to those of the controls, and rates on gravel pit access roads were even higher. Success rates on the other disturbance types were lower than those of the control sites.

Two major factors contributed to the low trapping success. Firstly, small mammal populations were low and secondly, traps were often triggered by evasive animals, hail or heavy rain and therefore were not effective if visited subsequently during that trapping period by small mammals. Ground squirrels presented a major problem, since they were numerous, attracted to the bait and too large to be captured. Traps sprung and robbed of bait accounted for 107 trap-nights and on four occasions, 100% of the traps in a line were tripped and robbed. On eleven occasions more than 75% of a trapline was tripped by rain or hail. In tall, shrub-dominated areas rain or hail triggered traps on the relatively exposed, disturbed sites more frequently than on controls. Altogether, 451 or 8.9% of the total 5,061 trap-nights were lost. If the success rate is recalculated, subtracting this number from the total trapping nights, it is 0.91 animals or 0.63 small mammals each 100 trap-nights (Table 5.1).

These results are comparable to those from undisturbed tundra regions. Martell and Pearson (1978) and Martell and Fuller (1979) reported 0.44 to 1.47 animals each 100 trap-nights over a 3 yr period at Tununuk Pt., N.W.T. The mean summer success rate was 0.86 averaged over the 3 yr period. Plant communities were dominantly sedge meadows and shrub tundra. Fuller et.al. (1977) averaged 0.646 *Dicrostonyx groenlandicus* in 100 trap-nights on Truelove Lowland. Four habitat types were sampled there.

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[13]One site had only seven traps for a total of 21 trap-nights because of space limitations

Table 5.1: Small mammal trapline results from CANOL Project disturbances, N.W.T., June to August 1979

Site Type	No. of trap lines	Varying Lemming	Least Chip-munk	Red-backed Vole	Long-tailed Vole	Meadow Vole	Heather Vole	Pika	Avifauna	Success rate in 100 trap-nights All animals	Success rate in 100 trap-nights Small mammals	Effective trap-nights
Control	28	3		5	1			1	2	1.12	0.93	1,073
Road	28	2		2				1	6	1.09	0.50	1,008
False Start Road	3			1						0.80	0.80	125
Bladed Trail	14			5					1	1.11	0.92	541
Camp Yard	1									0.00	0.00	35
Bulldozer Track	9			3						0.92	0.92	327
Gravel Pit	24			1					1	0.21	0.11	947
Gravel Pit Access Road	9		1	1			1		3	1.70	0.85	353
Oil Spill	5					1				0.50	0.50	201
Totals	121	5	1	18	1	1	1	2	13	$\bar{x}$=0.91	$\bar{x}$=0.63	4,610

The values presented in Table 5.1 take all of the lost trap-nights into consideration. Based on the corrected values for all animals, trapping success rates on controls were only slightly higher than those of bladed trails, roads and bulldozer tracks (Table 5.1). Gravel pit access roads had approximately 50 % higher success rates than were recorded for controls. Small mammal trapping success rates were highest and approximately equal on controls, bladed trails and bulldozer tracks (Table 5.1). Lowest success was found on the camp yard site (0.0 %) and in gravel pits (0.11 %). Success rates on road and oil spill sites were equal and slightly below average while those of false start roads and gravel pit access roads were well above the mean (Table 5.1).

Seven species of small mammals were trapped:

1. Red-backed vole (*Clethrionomys rutilus*)
2. Varying lemming (*Dicrostonyx torquatus*)
3. Long-tailed vole (*Microtus longicaudus*)
4. Meadow vole (*M. pennsylvanicus*)
5. Least chipmunk (*Eutamias minimus*)
6. Pika (*Ochotona princeps*)
7. Heather vole (*Phenacomys intermedius*)

The following four species of birds were trapped accidentally:

1. Water pipit (*Anthus spinoletta*)
2. Baird's sandpiper (*Calidris bairdii*)
3. Lapland longspur (*C. lapponicus*)
4. White-crowned sparrow (*Zonotrichia leucophyrus*)

5.4.2 Wildlife Sign Transects

A total of 132 transects were run, including 33 on control sites. The presence of resident wildlife was noted in the transects through signs such as pellet groupings and tracks. There was also evidence of small mammal activity in many areas. The most common large mammal was the woodland caribou, with sign on 56 transects. Least common were the red fox and the pika, each found on two transects (Table 5.2). Much evidence of Willow and Rock Ptarmigan (*Lagopus lagopus and L. mutus*) was found in the study area but it was not possible to distinguish between these species on the basis of

Table 5.2: Control-corrected values from wildlife sign transects on control sites and CANOL Project disturbances, N.W.T., June to August, 1979

Site Type	No.of Transects Sampled	Woodland Caribou Trk	Woodland Caribou Drop	Moose Trk	Moose Drop	Dall's Sheep Trk	Dall's Sheep Drop	Large Game Trail	Arctic Ground Squirrel Dig	Arctic Ground Squirrel Burw	Pika Drop	Pika Res	Other Small Mammals Drop	Other Small Mammals Burw	Red Fox Scat	Wolf Scat	Grizzly Bear Dig	Ptarmigan Drop	Wildlife Diversity
Control	33	2.6	1.5	8.0	1.7		3.5	2.0	1.0	1.6	1.0	1.0	6.7	12.8				4.0	7
Road	28	0.8	2.8	-1.3		3.0	4.3	0.5	7.8	0.5		1.5			1.0	1.2	2.5	3.1	9
False Start Road	3	1.5		1.0		1.0	3.0	1.0	22.0										4
Bladed Trail	16	8.3	0.0	-6.0	1.8	1.5	-2.0		1.0	1.3			4.0	-3.0		1.0	1.0	1.2	8
Camp Yard	1																	2.0	1
Bulldozer Track	9	2.7	4.7	1.0	1.0	2.0		-2.0	2.0	0.5			42.0	20.0	2.0	1.0		2.7	8
Gravel Pit	25	3.7	1.3	-3.0	-1.0	4.0	3.7	1.0	5.0	1.0			2.0					1.8	6
Gravel Pit Access Road	9	4.2		-3.0	0.5	1.0	2.5		53.5	0.0								2.5	5
Oil Spill	7	2.5	1.0	1.0	1.0	4.0	1.0				1.0		8.0					5.0	6

'-' lower than control value; '0.0' same as control value; 'Trk' track; 'Drop' dropping; 'Dig' digging; 'Burw' burrow; 'Res' resident

sign alone. Numerous other birds were also observed but such sightings were not recorded.

Evidence of use or sightings of the following large mammals was noted:

1. Moose (*Alces alces*)
2. Wolf (*Canis lupus*)
3. Siberian lemming (*Lemmus sibiricus*)
4. Dall's sheep (*Ovis nivicola dalli*)
5. Woodland caribou (*Rangifer tarandus caribou*)
6. Arctic ground squirrel (*Spermophylis parryii*)
7. Ermine (*Mustella erminea*)
8. Wolverine (*Gulo gulo*)
9. Grizzly bear (*Ursus arctos*)
10. Red fox (*Vulpes vulpes*)
11. Marmot (*Marmota caligata caligata*)

By tallying the number of species and groups of animals, a rough index of the diversity of the wildlife using each site can be derived. A perfect diversity index score would be 10, since 10 major categories of animals were recorded (Table 5.2). Controls averaged an index value of seven. Road, bladed trail and bulldozer track sites were used by a greater variety of animals than were controls while camp yard populations were the least diverse with an index value of one (Table 5.2).

5.5 Discussion

Of the methods employed, the transects provided the largest, most comprehensive data base. However, conclusions regarding the effect of CANOL disturbances on resident wildlife are based on all data sets.

5.5.1 Small Mammal Traplines

The low number of small mammals taken from controls indicated that populations in the region were low. In periods of low abundance competition for preferred habitats would be minimal. The fact that several disturbances had populations exceeding those of controls therefore indicates that these man-altered systems were highly desirable and

were selected by small mammals when a choice of habitat types was available.

Many small mammal habitats have been created by the CANOL disturbances. Success rates were relatively low on all types of disturbed sites but were most similar to controls on bladed trails and bulldozer tracks, indicating that small mammal populations have been least affected by these types of disturbances. The long-tailed vole was the only small mammal not found on a disturbance, while, the least chipmunk, meadow vole and heather vole were found only on disturbances (Table 5.1). Insufficient data exist to discuss any trends in detail, however, these data suggest that certain species are more tolerant to disturbance and may even prefer disturbance habitats.

5.5.2 Wildlife Sign Transects

Animal signs confirm the presence of a species in a particular area but do not necessarily indicate what attracted the animal to that area, the type of use, or the amount of time spent there. In some cases, observations supported hypotheses regarding timing and use but sufficient information of this type was not collected to make firm conclusions. However, when viewed together, transect and observational data do provide information regarding species presence/absence and the relative intensity of use of various sites.

Summer droppings of ptarmigan were not detectable on the transects since the summer diet of lush, moist vegetation does not produce the dry, persistent droppings created by the winter diet of buds and twigs. The transect data therefore provide some indication of winter and fall use but not reflect spring or summer ptarmigan activ

The transect results can be viewed from two perspectives:

1. frequency of use by an animal of a site type (i.e. oil spill) as indicated by a particular type of animal sign (i.e. caribou tracks); and
2. the percentage of sites of a particular type having a given type of animal sign

The first approach gives the magnitude of the differences among controls and disturbances (i.e. 'control corrected' values discussed in Section 3.4), whereas the second provides an indication of site preference based solely on the type of disturbance.

Table 5.2 presents control-corrected values for all disturbances and shows the average control values for comparison. When sign was noted, values on roads were

consistently higher than those of controls, with the exception of moose sign. Small mammal sign was lacking on roads while fox, wolf and bear left no evidence of use on controls. Resident pika were seen on the road but appeared to be residing in adjacent undisturbed areas. False start road values were relatively low, with the exception of arctic ground squirrel diggings and Dall's sheep. Pika and small mammal sign, while evident on control sites, was absent from false start roads. When sign of these animals was found on disturbances, the values were consistently higher than those of the controls.

On bladed trails, caribou sign was more frequent and moose sign much less common than on associated controls. The camp yard had higher values for ptarmigan sign than did its control. A substantial difference was found between small mammal sign on bulldozer tracks and that on controls. Moose sign was less frequent in gravel pits than in controls but, when present, other animals consistently appeared to occur more frequently in the gravel pits. Gravel pit access roads had a higher frequency of caribou tracks and ground squirrel diggings than did their controls. However, evidence of use by pika and other small mammals and game trails was absent.

Oil spills posed a special case since animal sign on these sites could be preserved for long periods of time. The waxy or tarry residue on the surface retains impressions left from animal passage and the chemically hostile substrate harbours few bacteria or fungi capable of decomposing droppings. Consequently, estimates of use on these sites may appear much higher, than is the case relative to other sites. The lack of vegetation on spills offers no opportunity for foraging and associated digging activity. Ground squirrel burrowing sign was also absent.

A tally of the number of animal signs, illustrates how frequently disturbances are used in comparison to control sites (Table 5.2). The sign counts also provide some information regarding magnitude of use in the areas where they are found but do not necessarily reflect the sites' potential for use. Comparisons of the percentage of control sites with a particular sign and the percentage of disturbed sites with that sign suggest site preferences (Table 5.3).

Only one camp yard and three false start roads were sampled and the results recorded for these site types are therefore inconclusive. Game trails, ground squirrel trails and burrows and sign of pika and other small mammals appeared in a greater

Table 5.3: Percentage of wildlife sign transects on control sites and CANOL Project disturbances, N.W.T. with evidence of use, June to August, 1979

	Woodland Caribou		Moose		Oall's Sheep		Large Game	Arctic Ground Squirrel		Pika		Other Small Mammals		Red Fox	Wolf	Grizzly Bear	Ptarmigan
Site Type	Trk	Orop	Trk	Drop	Trk	Orop	Trail	Oig	Burw	Orop	Res	Orop	Burw	Scat	Scat	Oig	Orop
Control	36	6	3	9	0	6	6	6	30	3	6	9	15	0	0	0	9
Road	29	14	11	0	4	21	7	18	4	0	4	0	0	4	14	7	32
False Start Road	67	0	33	0	33	67	33	33	0	0	0	0	0	0	0	0	0
Bladed Trail	50	13	6	25	13	19	0	19	19	0	0	13	6	0	6	13	31
Camp Yard	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
Bulldozer Track	67	33	11	22	11	0	11	11	44	0	0	22	22	11	11	0	33
Gravel Pit	40	12	8	8	4	12	4	12	4	0	0	4	0	0	0	0	16
Gravel Pit Access Road	67	0	11	22	11	22	0	22	11	0	0	0	0	0	0	0	22
Oil Spill	57	14	14	29	14	14	0	0	0	14	0	14	0	0	0	0	14

'Trk' track; 'Orop' dropping; 'Oig' digging; 'Burw' burrow; 'Res' resident

percentage of the bladed trail transects than of controls. Conversely, Dall's sheep droppings and pika sign were found in a smaller percentage of the bulldozer tracks than of the control sites. Gravel pits and their access roads had fewer game trails, ground squirrel trails, droppings and burrows, and less sign of pikas and other small mammals than did controls. The percentage of the gravel pit access roads with caribou droppings was less than was recorded for the control sites. Similarly, moose sign was less frequent in gravel pits than in undisturbed areas.

5.5.3 Summary Discussion

The trends apparent in the results from the small mammal traplines and wildlife sign transects are further supported by field observations. A summary of the trends and their relevance to resident wildlife responses to CANOL disturbances indicates that not all impacts have been negative in the long-term. Similar trends were noted by Lore (1977) for cart track disturbances on the Burwash Uplands.

For arctic ground squirrels, disturbances have increased the amount of available habitat in some areas. This is particularly important in wet areas where the roads, false start roads, gravel pit access roads or gravel pit spoil heaps provide elevated, well-drained, sites suitable for burrows. In such areas burrow entrance densities of as high as one in every 2 m^2 were recorded on disturbed sites. Similar densities were noted on naturally occurring elevated sites. Raised sites also offer a broader field of vision for ground squirrels on the lookout for approaching predators. All Camp sites had relatively high populations of ground squirrels. For example, at Camp 80, approximately 23 animals were recorded in 1979 and 8 of these were young of the year. At least 4 adults had burrows beneath camp buildings and all of the CANOL structures were being used for cover. By contrast, no ground squirrels were seen in undisturbed areas on the surrounding Plains of Abraham.

Small groups of bull caribou were observed most frequently approaching and utilizing disturbed sites. Groups of as many as 31 cows and 15 calves were noted using areas to within 0.5 km of disturbances. Only a small number of sightings of groups on disturbances were made and any conclusions require more information in order to test their reliability. Caribou overwinter at lower elevations and none were sighted in the study

area during the winter surveys. A small herd of 8 was seen above R.M.P. 62 in late April 1979.

Solitary caribou frequently altered their line of travel to follow a linear disturbance. This may have been a response to the greater ease of movement afforded by the smoother surfaces, relatively solid footing and lack of encumbering shrub cover that may be found on such features. The herbaceous and woody forage, which often flourishes on these sites, is often composed of forage species that are rare or absent in the undisturbed areas. Furthermore, the view from an elevated surface is less restricted, an important factor where predators are concerned, and such areas are more open to the wind, thereby providing a cooler, relatively insect pest-free area.

Fewer data were collected for moose than for caribou, indicating that moose seldom used these disturbances. Unlike caribou, moose are primarily browsers and prefer to travel through dense shrub vegetation. They spend much of their time in wetlands and are therefore unhindered by unsure footing. Their thick hides protect them from many of the small, biting insect pests that bother caribou and heat stress is not a problem, since moose generally have easy access to water bodies that remain cool throughout the summer. Consequently the firm, raised surfaces created by the CANOL Project provide no great advantage for this species. The location of the road also may be an important factor since preferred moose habitat, the wetlands was, understandably avoided by constructors whenever possible. Consequently, preferred moose habitat and CANOL disturbances tend to be mutually exclusive. A number of moose trails were seen during the winter in the western end of the study area. One of these extended along the road for several hundred meters but most crossed at various angles without significant directional changes.

Observational data indicate that sheep encountering roads will usually follow them, utilizing the roadbed for travel and sporadic grazing. This was noted most frequently in the Plains of Abraham area, where the flat plateau surface offers an unrestricted view enabling alert sheep to spot approaching predators with ample time to seek out the nearby refuge offered by the nearby cliff walls.

The road is the major disturbance in the Blue Mountain area as it generally follows the contours around the mountain The winding route of the road, the great elevation

change and the large number of draws provide many hidden approaches to predators for stalking prey. Sheep in this area were seen primarily on the steeper slopes above the road where there was ready access to escape routes, and they tended to move up and down the face of the slopes at right angles to the road rather than follow along it. At Pump Station No. 4, several separate bands of sheep moved into the camp yard during the day to feed on herbaceous and woody forage. In this case, the cliff immediately behind the camp provided an escape route.

During the winter, when travel routes intercept disturbances that offer less impediment to movement (a result of harder, thinner snow cover), sheep were often noted to alter course to follow these until conditions changed.

Foxes and wolves were frequently seen moving along the road. The increased range of view and reduced impediment to movement were undoubtedly important factors in this preference. However, the relatively high concentrations of prey species such as ground squirrels and ptarmigan may also be important. The large ptarmigan populations in the western half of the study area are probably an important summer food source for resident canines.

Ptarmigan are the most frequent users of the road, particularly where it passes through shrub tundra. These ground dwelling birds seldom fly, preferring to run from predators, and to take flight only as a last resort. The road, gravel pit access roads, gravel pits, and in come cases, bladed trails provide sites where ground–level vegetation is often sparse and footing is firm. When such sites are linear they offer ideal escape routes from predators. Elevated disturbances also supply exposed sources of crop gravel during the winter and dry sites for summer dust baths. In all seasons, ptarmigan strongly prefer disturbed sites to undisturbed areas. The transect results, which reflect winter use only support this (Table 5.2). The only winter sighting of wildlife of any kind on the Plains of Abraham was a pair of Rock Ptarmigan browsing on *Salix alaxensis* along a bladed trail.

Rand (1946) noted Cliff Swallows along the CANOL route. However his easternmost record was made at R.M.P. 218W (110 km west of Macmillan Pass) and "a colony of twelve to eighteen birds was seen under a new wooden bridge" at Ross River (1946:47). Currently, Cliff Swallows are found in buildings and under bridges throughout

the western portion of the study area and have extended their range as far east as R.M.P. 208. Prior to 1945, these birds were nesting at Ross Post on long established buildings and so were able to quickly colonize the newly created nesting sites provided by the CANOL Project structures. Their current distribution suggests that they have yet to occupy CANOL tundra sites further to the east.

The swallows are only one example of a species able to utilize some of the micro-habitats created by the Project above timberline. Other examples include the birds taken in the traps (Section 1.4). Their presence indicates that the local avifauna utilize many of the disturbances. More information is necessary in order to clarify these interactions.

The presence of a bushytail woodrat at Camp 208 indicates that opportunities exist for the transplanting of exotic species into these areas. With the establishment of breeding populations, exotic species could then compete with native species for the available resources.

5.6 Conclusions

It is evident that most of the disturbed areas associated with the CANOL Project are currently used by resident wildlife. However, not all disturbances are utilized to the same degree. Preferences may be related to a wide variety of local environmental characteristics, including snow distribution, snowpack characteristics, vegetation structure and composition, substrate characteristics and atitude of the disturbance. Not all species utilize disturbed sites to the same degree or for the same reasons. The effects of linear disturbances are similar in many ways to those of riparian systems. Both pass through otherwise homogeneous areas and thereby increase habitat diversity. Such 'edge' or 'ecotone' habitats can be areas of enhanced wildlife productivity (Odum 1971). However, some disturbances such as oil spills and some gravel pits are essentially sterile and have resulted in reductions in the amount of available habitat.

These abandoned CANOL disturbances were 34 to 36 years old in 1979. They displayed quite different characteristics shortly after their initiation. Following abandonment, there may well have been several years or more during which disturbances were avoided by wildlife. Reasons could include the relative sterility of these sites which

supported little forage and the presence of something 'new' in the environment to which animals were as yet unaccustomed.

6. A SYNTHESIS OF THE LONG-TERM ECOLOGICAL CONSEQUENCES OF CANOL DISTURBANCES

6.1 Introduction

Data and discussions in the previous chapters have dealt individually with the major components of the ecosystems affected by the CANOL disturbances – substrate, vegetation and wildlife. However, little of the interaction among these components was discussed. Therefore the purpose of this chapter is to present a more integrated approach, recognizing the importance of the interaction of the main components and interrelationships effecting the production of unique responses to environmental alterations. This is in accordance with the overall purposes of the study (Section 1.3). In part, this is accomplished by the presentation of schematic illustrations or models of the environments and the differences that exist between disturbed and undisturbed ecosystems..

As in other chapters, this discussion is based upon plant communities. With this approach, the environmental alterations resulting from each type of disturbance can be compared within one type of tundra.

6.2 Ecological Consequences of CANOL Disturbances

The choice of parameters discussed below was based upon the relative importance of each component and the amount of data available. Substrate moisture content, particle size composition, organic matter content and temperature in the upper rooting zone are all considered important factors influencing plant colonization and geomorphological processes. Plant productivity and cover are major indicators of plant community responses and will also affect use of the area by most resident wildlife. However, pellet/scat counts of the most common wildlife species are considered since, of the data available, these were felt to reflect most accurately the level of use by resident wildlife. Ground squirrel droppings were seldom seen, though this was by far the most common mammal in the study area. Therefore, transect counts of ground squirrel diggings, associated with foraging, were used as an indicator of relative degree of use by this species.

The interrelationships of parameters within each of these groups are complex, as are the interactions between groups. A change in one parameter may affect another and this, in turn, may alter the initial component. An example of such a feedback interaction can be seen where a road produces a raised, well-drained surface. The road shoulders are moister than the centre of the road due to the concentration of runoff and relatively low compaction on these sloping surfaces. As a result, *Salix alaxensis* colonizes the shoulder more readily and the erect shrubs trap drifting snow which, upon melting, further enhances the substrate's moisture status.

The illustrations that are provided present the mean value for each parameter for the controls sampled. This is followed by the mean of the differences from the controls that were found for each disturbance type studied in that community (see Sections 3.3 and 4.2.3.2 for elaboration).

6.2.1 Erect Deciduous Shrub Tundra

The key differences between most disturbances and their controls in this plant community were in greater gravel content and lower organic content in the surface layers (Figure 6.1). Such changes have led to reduced moisture content and higher temperatures on disturbances. Exceptions to this occurred on oil spills and bulldozer tracks. Substrate differences have provided conditions for plant community development on disturbances that have only some characteristics in common with control communities. The area of bare ground was greater and phytomass much reduced on all types of disturbances. Based on similarity coefficients, it appears that local species are well adapted for colonization and can survive limited surface disturbance. Where surface organics were mixed with mineral material (i.e. false start road and camp yard sites), floristic diversity was enhanced. These changes have provided wildlife habitat on disturbances that was preferred by most resident species. Key factors in this development are the availability of preferred forage and greater ease of movement with no reduction in the availability of cover.

Overall, oil spill disturbances appear to have least in common with the control sites (Figure 6.1). Variations on this type of disturbance are reflected most directly through botanical responses since the major substrate alterations were chemical rather

than physical. Gravel pit access roads consistently were most similar to undisturbed areas with respect to substrate and botanical characteristics, followed closely by bulldozer tracks which showed greater increases in use by resident wildlife.

Several trends became apparent from the control–corrected data analysis (Figure 6.1). Moisture content increases parallel increases in organic matter, suggesting that these two parameters are strongly interdependant. Organic matter absorbs water and reduces losses through evaporation and surface/subsurface drainage and increased moisture leads to the greater accumulation of organic material.

The fine sand and silt/clay content was the only substrate component with alteration trends parallelling those of botanical parameters. As the fine particle content increases, so do above–ground phytomass and species richness. Although phytomass was greatly reduced on all disturbances in this community, reductions were least on those sites with the higher fine particle fraction. Finer particles would retain moisture and supply nutrients more readily than would coarser substrate materials. These trends are apparent for most disturbance types, with the notable exception of oil spills.

Use by woodland caribou appears to increase with increasing above–ground phytomass. Much of the phytomass on disturbances in this type of tundra was in the form of shrubs such as *Salix alaxensis* and *S. planifolia* (Figure 6.1). Caribou often have been observed browsing on these species, suggesting that they forage on disturbances because of their greater willow cover. Greater use by moose generally parallelled increases in vascular plant cover, suggesting a relationship between their presence and the availability of preferred browse. Arctic ground squirrel use increases as substrate moisture and organic content decline relative to control values. These rodents generally select burrow and foraging areas that are well–drained and have thin organic layers. Disturbances such as roads and gravel pit overburden spoil heaps provide such habitats.

6.2.2 Decumbent Shrub Tundra

Disturbance substrates in this community vary considerably from those of the controls. In all cases, gravel content has increased and organic matter decreased (Figure 6.2). This occurs to a greater extent on bulldozer tracks than on other, seemingly more

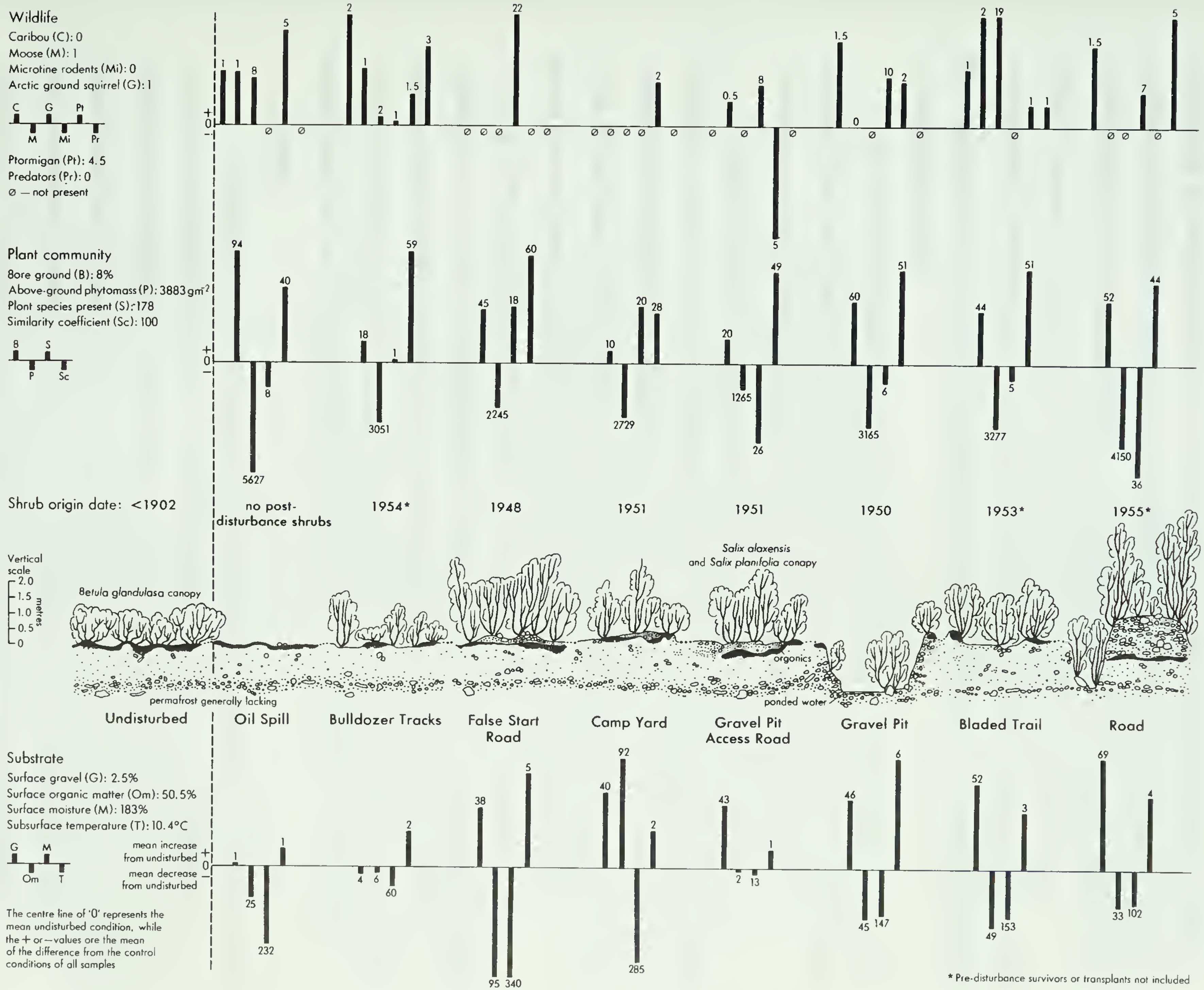


Figure 6.1 Idealized section with selected ecological characteristics of CANOL Project disturbances in Erect Deciduous Shrub Tundra, N.W.T.

disruptive, disturbances. Moisture content was generally lower and temperatures higher than on undisturbed sites. Plant communities reflected these differences with a greater percentage of bare ground and a simplified species composition. However, similarity coefficients indicate that disturbance communities were reasonably similar to those of their controls. An important exception to this trend occurred on oil spills, where little floristic similarity to control plant communities was indicated. Phytomass on all disturbances was much lower than that of control communities. Resident wildlife used disturbances and all but Dall's sheep demonstrated a preference for these sites relative to undisturbed areas.

The greatest impacts in this type of tundra appear to have been associated with oil spills. Many disturbances were very similar in their degree of variation from control conditions and it is difficult to describe any one type as having been least altered.

Several trends and relationships between relative values of parameters are apparent from the control-corrected data (Figure 6.2). Increasing gravel content generally parallelled increasing above-ground phytomass. This probably was due to the greater tall shrub cover found on disturbances with gravelly substrates (e.g. roads, false start roads, gravel pits and gravel pit access roads)(Figure 6.2). With few exceptions, higher above-ground phytomass corresponded with higher organic content. This is to be expected, as a rise in one would enhance directly the production of the other. Increasing sand-silt/clay content corresponds with smaller declines in organic matter and lower subsurface temperatures. The insulation afforded by the organic material would reduce ground heat flux and therefore result in temperatures more similar to those of the control sites.

As the organic matter content of these substrates increases, so does the floristic similarity of disturbed and control sites. This can be a result of a lower degree of disturbance, as reflected in organic matter. However, the lack of organic material is also a major factor limiting the survival of local species on disturbances in this plant community. This relationship is further supported by the fact that cover by lichens, a dominant component of this community, corresponds with increases in both above ground phytomass and substrate organic matter content. As vascular plant cover increases, so does species richness. However, no such relationship with lichen and bryophyte cover

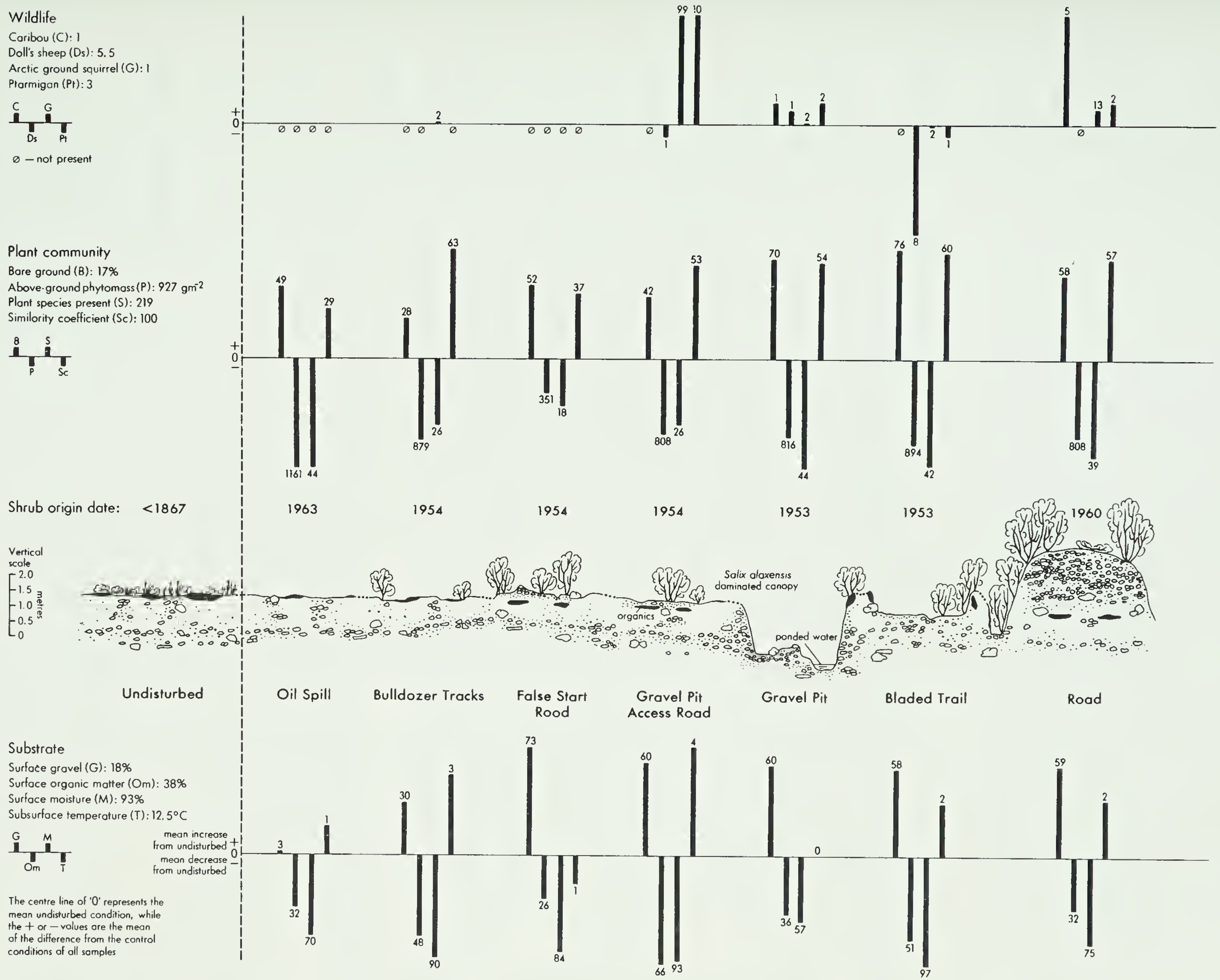


Figure 6.2 Idealized section with selected ecological characteristics of CANOL Project disturbances in Decumbent Shrub Tundra, N.W.T.

was noted, indicating that the number of species present on disturbed sites was controlled most directly by vascular plant taxa.

Caribou, rodent and ptarmigan use all declined as the amount of bare ground increased. This was probably a direct response to reductions in forage and cover, suggesting that disturbed sites in this community were preferred because of the presence of new plant species, rather than the absence of control characteristics.

6.2.3 Sedge Meadow Tundra

Organics dominate the soils in this plant community. However, some disturbances were mineral–dominated when excavated into or constructed above predisturbance surfaces (Figure 6.3). Excavations in the organics resulted in the concentration of surface water and greater soil moisture. Subsurface temperatures increased when gravel produced drier soil conditions. Plant communities on disturbances were markedly different from those of their controls, despite little substrate difference in some cases. Bare ground increased substantially on most sites, coupled with a decline in phytomass. Disturbance plant communities were more complex structurally as a result of the growth of an erect shrub layer. This resulted in increased cover and preferred forage for wildlife. However, where surfaces had been lowered (i.e. Gravel pits and bladed trails), views were more restricted and footing less sure and as a result animals avoided these disturbances.

Considering all of the parameters presented in Figure 6.3, oil spills and roads have had by far the greatest impact in this community. The substrate and botanical characteristics of bulldozer tracks are most similar to those of the controls but levels of wildlife use were significantly higher on this disturbance. Conditions on bladed trails were similar, but the pattern less clear.

Several trends are apparent from the control–corrected data (Figure 6.3). Relative increases in moisture content parallel increases in both sand–silt/clay and organic matter content. The water–holding capacity of the finer particles and organic material would enhance substrate moisture content on disturbances where these components were greater than in controls. The large increase in moisture on bladed trails was due to depressions associated with these features and the subsequent ponding of water. The

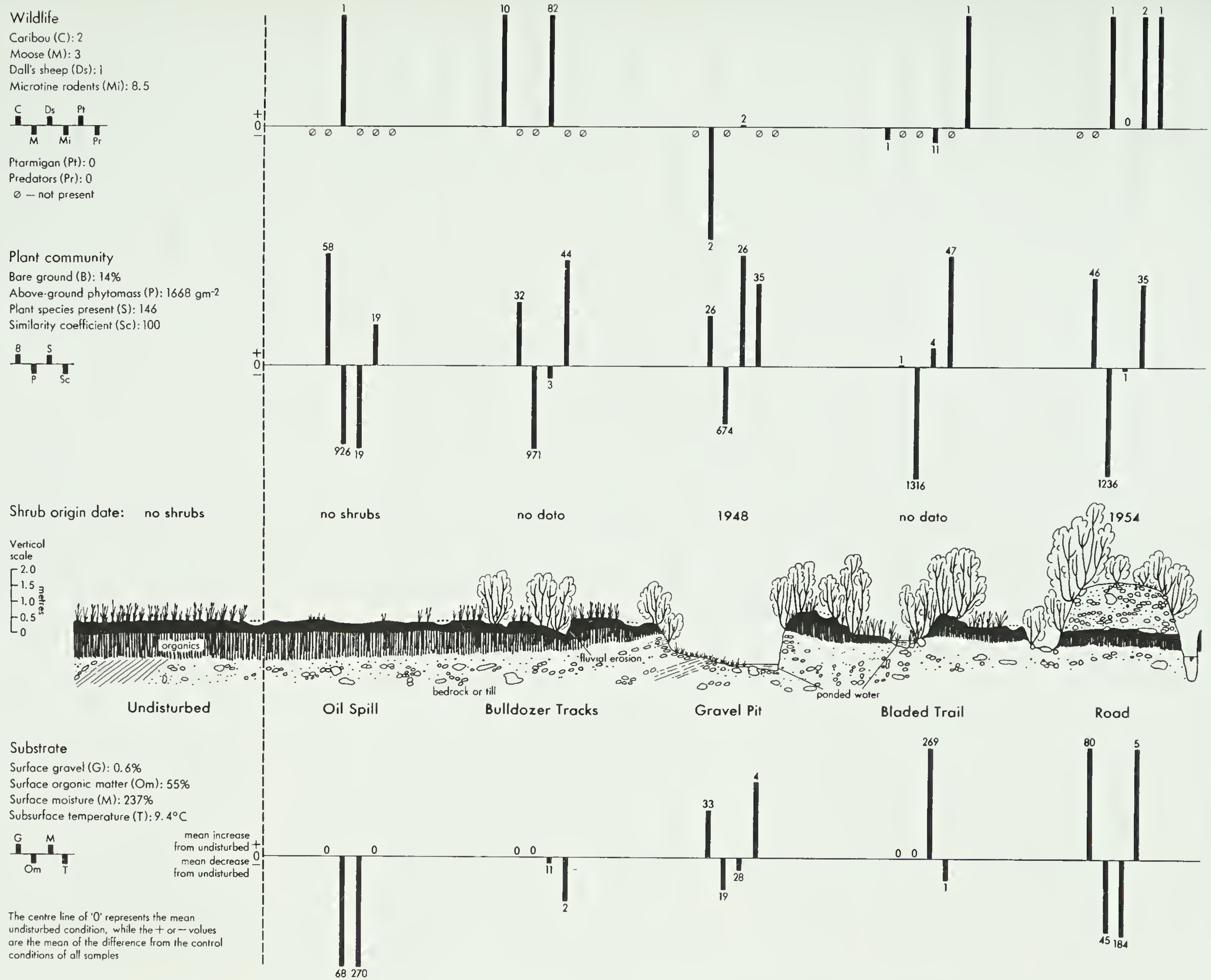


Figure 6.3 Idealized section with selected ecological characteristics of CANOL Project disturbances in Sedge Meadow Tundra, N.W.T.

relationship between increasing gravel content and rising subsurface temperatures was expected, since these raised, dry substrates with free drainage should generally be warmer.

Increasing moisture content also corresponded with decreasing bare ground and increasing floristic similarity with controls, suggesting that moisture is the major factor determining the success or failure of local species invading disturbances in this community. Bryophyte and lichen cover increases were inversely related to the amount of bare ground, indicating that these were the most important recolonizers in this type of tundra and that these plants were best suited to colonizing sites where limiting factors were minimal. Excluding road sites, a direct relationship is also apparent between bryophyte, lichen and vascular plant cover values and species richness. This suggests that a variety of species, rather than one or two dominant plant types, were responsible for relatively high cover values on disturbances in this community.

Rodents were found only on the three disturbance types with the highest total plant cover. This could be a reaction to the greater availability of food or to the increased amount of cover and protection from predators. Dall's sheep and ptarmigan, on the other hand, were found only on the two sites with the least plant cover, suggesting that they selected sites for reasons such as ease of movement and unrestricted view. The presence of exposed, mineral surfaces, rarely found in undisturbed areas, provided ptarmigan with crop stones and silt in dried puddle beds was often used for dust baths by both sheep and ptarmigan.

6.2.4 Lichen Heath Tundra

In Lichen Heath Tundra, disturbances produced substrates with more gravel and less surface organic matter than was found under control conditions. These changes produced drier, warmer substrates and resulted in less plant cover and lower phytomass values than were recorded from control sites. Bladed trails had greater species richness and the greatest floristic similarity with controls. Other disturbances had low similarity coefficients. Structural changes resulted from the growth of *Salix* shrubs and may explain, in part, why wildlife sign was noted only on those disturbances where increased cover, ease of movement and enhanced field of vision were afforded.

Considering all of the major ecological characteristics, oil spills have had the greatest impact in this plant community. Roads and bladed trails are most similar to control sites, but all disturbances have resulted in substantial changes from control conditions.

Several trends are evident among disturbances in this plant community (Figure 6.4). Declines in bryophyte cover parallel increases in moisture since the most common colonizers in this group, *Polytrichum* species, prefer drier substrates. The greater the degree of floristic similarity with controls, the greater the species richness. Therefore, local species have been most successful in invading these disturbances and these habitats are capable of supporting a wide variety of plants. However, when revegetation was limited to a few species, these generally came from areas outside of the associated controls, indicating that local species could not survive or were poorly adapted for colonization of sites that had been substantially altered by the disturbances.

Reductions in the amount of bare ground parallel increases in substrate organic content, above-ground phytomass and vascular plant cover. This suggests that vascular plants form the major portion of the phytomass on these disturbances, and as such, contribute directly to the rate of accumulation of organic matter. High organic content would also enhance plant growth and is probably a major factor controlling the success of the vascular plants colonizing these disturbances. Lichen cover was much lower on disturbed sites than on controls in this plant community while subsurface temperatures were dramatically higher. The lichen layer would reduce ground heat flux and consequently its removal would enhance heat penetration during the summer.

6.2.5 Fruticose Lichen Tundra

The increase in gravel and removal of surface organic matter produced drier substrates on all disturbances in Fruticose Lichen Tundra (Figure 6.5). Total bare ground was greater and phytomass much reduced on all disturbances relative to control conditions. However, species richness was greater than that of the controls on all disturbances with the exception of gravel pits. Similarity coefficients show that plant communities on disturbances were not radically different from those of the undisturbed areas. Since wildlife sign was greater on all disturbances and no sign was found in the

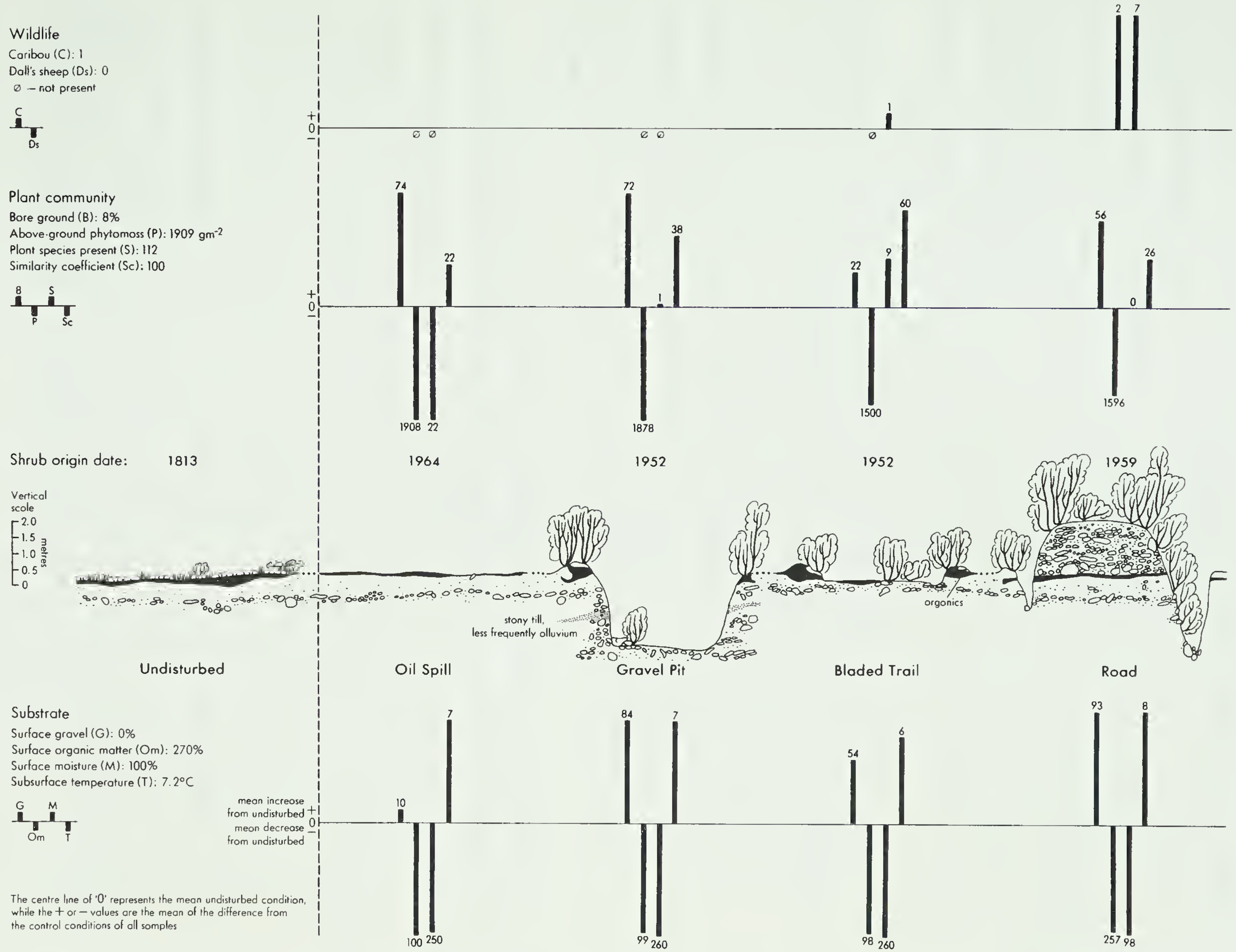


Figure 6.4 Idealized section with selected ecological characteristics of CANOL Project disturbances in Lichen Heath Tundra, N.W.T.

contols sampled, it is evident that there was a strong preference for disturbances. Disturbances have provided wildlife habitats not otherwise available in this type of tundra. Significant factors in this would include increases in cover, forage availability, ease of movement and field of view.

Considering all three groups of parameters studied, bulldozer tracks are most similar to the control areas, followed closely by gravel pit access roads. No disturbance was consistently least similar to the control sites. However, roads showed several of the greatest differences throughout and were greatly preferred by wildlife. Roads are therefore considered to have had the greatest long-term impact in this plant community.

Certain relationships and trends emerge from analyses of the control-corrected data (Figure 6.5). Increases in gravel content generally parallel increases in subsurface temperature as the coarser substrates are more capable of conducting heat energy. However, for this reason, the warmest substrates during the summer could also be among the coldest during the winter. With the exception of road sites, increases in temperature correspond with decreases in phytomass, suggesting that extreme surface temperatures are a major factor limiting plant production on disturbances in this community.

Increases in species richness correspond with increasing vascular plant cover values, indicating that vascular plants are the most important component contributing to species diversity on these disturbances. Increases in phytomass correspond with declines in similarity coefficients, suggesting that those species producing the greatest percentage of the phytomass on disturbed sites were migrating in from other areas. The three types of disturbances with the highest vascular plant cover and highest species richness were the only sites with sign of ptarmigan or caribou use. In addition to this, increasing use by Dall's sheep corresponded with increases in vascular plant cover and species richness. Since no one species consistently had high cover values on disturbances, it seems probable that these animals were selecting sites on the basis of the diversity of vascular plants available for forage and/or cover.

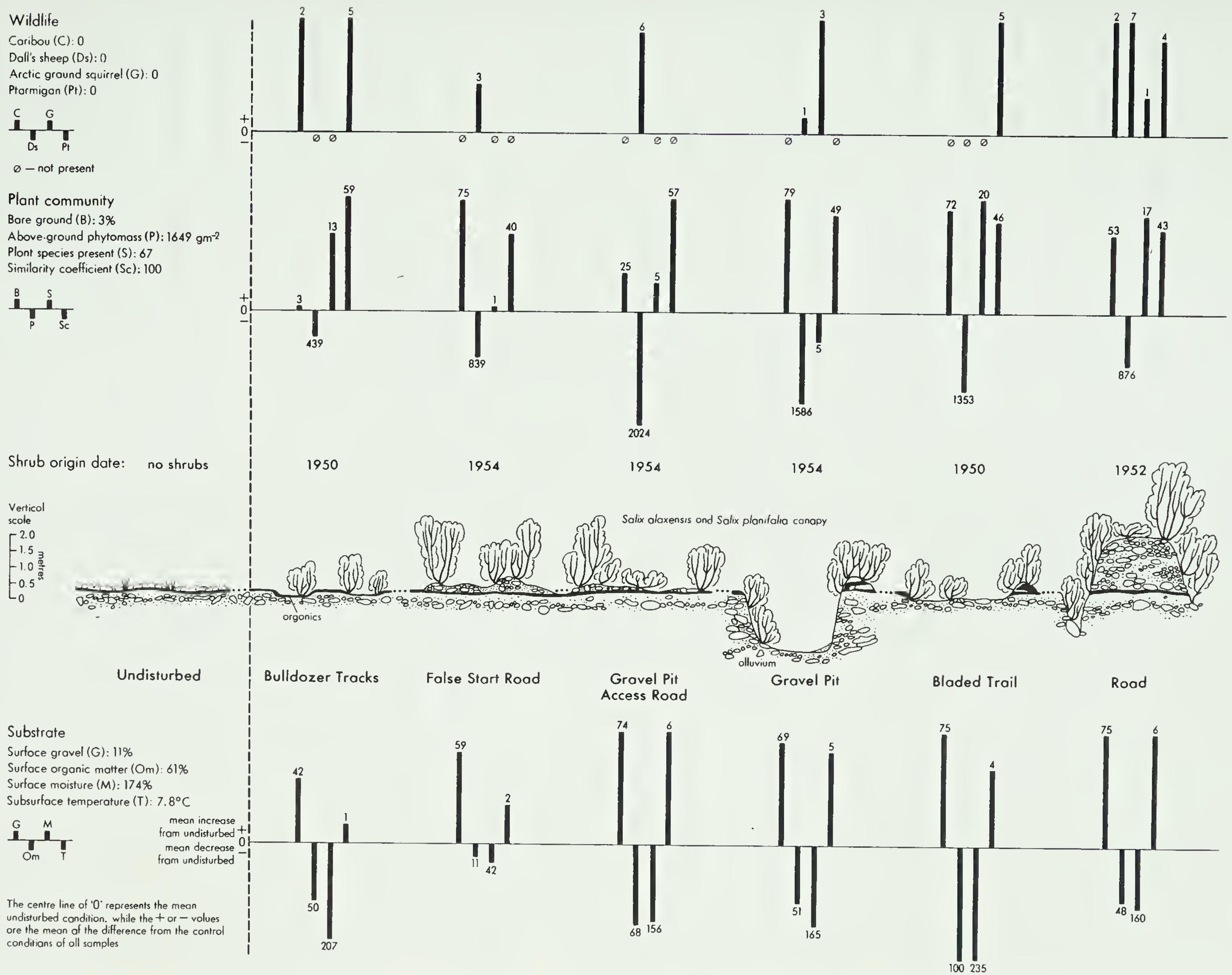


Figure 6.5 Idealized section with selected ecological characteristics of CANOL Project disturbances in Fruticose Lichen Tundra, N.W.T.

6.2.6 Cushion Plant Tundra

In Cushion Plant Tundra, most disturbances had substantial increases in gravel content relative to their controls. However, moisture and organic matter content varied little from control conditions. Subsurface temperatures were warmer than those of undisturbed areas on bladed trails and roads only. Since control sites were bare for an average of 57% of their surface (Figure 6.6), the increases in bare ground found on all disturbances were small, relative to those recorded from other communities. Phytomass and species richness was lower on all disturbance types than in control areas. However, despite this, floristic similarity coefficients were high. Resident wildlife demonstrated a preference for disturbed areas. On roads, the presence of preferred forage (*Salix alaxensis*) and a smooth travel way attracted both sheep and ptarmigan. Overall, gravel pit access roads had the least impact on this community. The greatest differences from control conditions were generally associated with road sites.

Several trends are apparent from the control–corrected data presented in Figure 6.6. Increases in gravel content parallel reductions in moisture content. This can be related to the improved drainage of these coarse substrates and the fact that such disturbances are often raised above the surrounding terrain and therefore have increased runoff.

Increases in bare ground parallel decreases in lichen cover, indicating that lichens are found primarily on areas with the largest plant coverage and therefore probably on the least altered disturbances. Increases in fine–textured particles, phytomass and vascular plant cover also appear to be directly related. The relative enhancement of nutrient supply and moisture retention associated with a high fine particle content could result in the improved growth of plants and the consequent accumulation of above–ground phytomass. These substrates would be particularly suitable for the establishment of the vascular plant species colonizing disturbances in this community. These data also suggest that a large percentage of the phytomass on disturbances was produced by vascular plants.

The greatest sign of wildlife use was generally found on those disturbances with the largest bare area. In this type of tundra, the patchy and prostrate control vegetation presents no hindrance to movement or view. However, disturbances do provide relatively warm, often raised or protected areas with few surface irregularities.

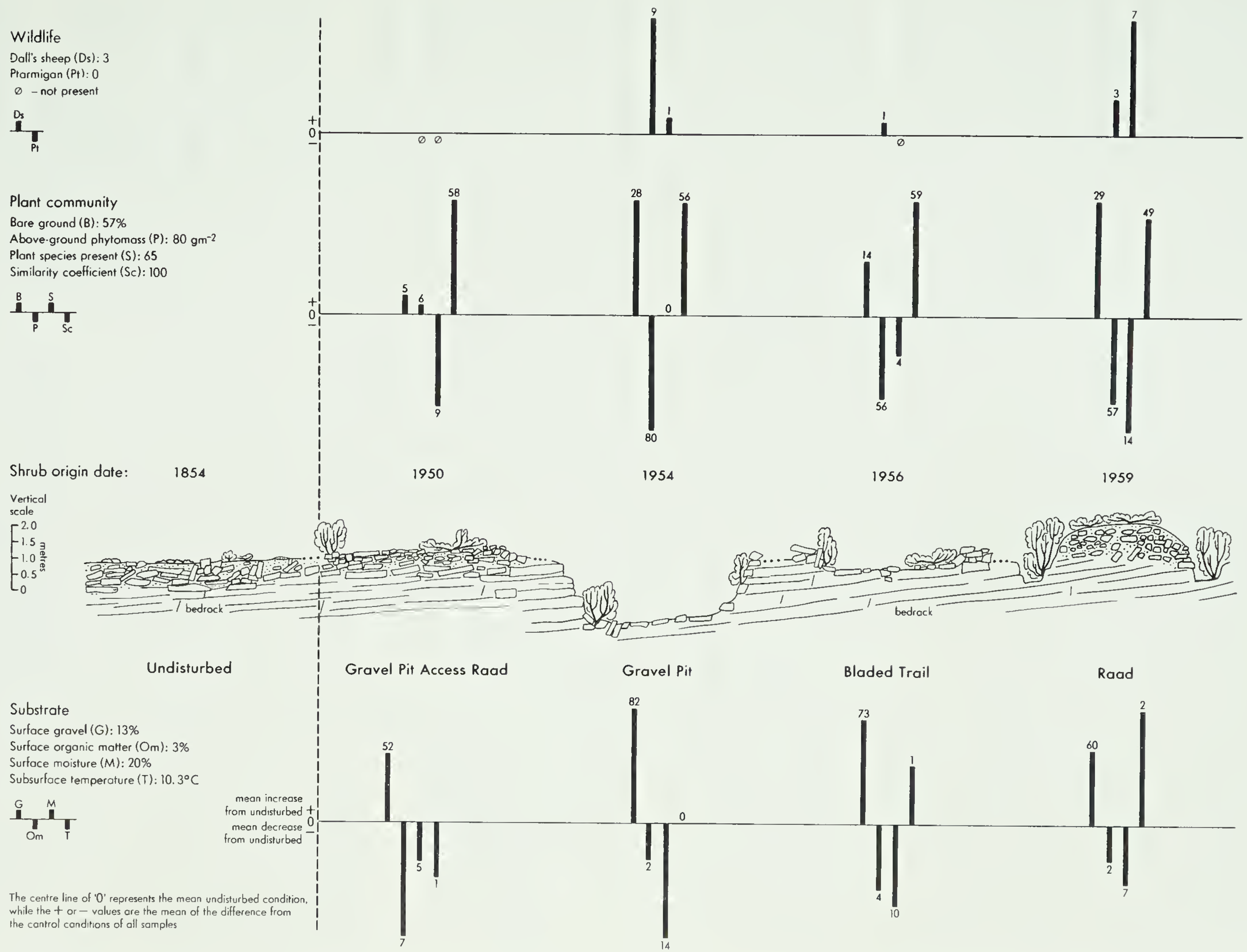


Figure 6.6 Idealized section with selected ecological characteristics of CANOL Project disturbances in Cushion Plant Tundra, N.W.T.

6.2.7 Crustose Lichen Tundra

The altered substrate conditions associated with most of the studied disturbances had very different effects in Crustose Lichen Tundra than in other plant communities. These control substrates were gravel-dominated and covered by a dark layer of lichens. Consequently they were generally warm. Gravel pit and road disturbances were more gravelly than control areas but roads contained sufficient fine-textured material to promote greater water retention. In all cases, substrate temperatures on disturbances were lower than those of the controls. Disturbed sites also had greater bare area and less phytomass than was found in control communities. Colonization by vascular plants resulted in increases in species richness and produced plant communities that had little in common with those of undisturbed areas. Overall, gravel pits appear to have had the greatest impact on this community and bladed trails, the least. Several trends are apparent from the control-corrected data (Figure 6.7). Increases in moisture content correspond with increases in vascular plant cover, suggesting that moisture availability is a major factor limiting vascular plant colonization in this type of tundra. Lichen and bryophyte cover increases parallel reductions in bare ground and increases in above-ground phytomass. This would seem to indicate that non-vascular plants are important recolonizers only on those sites with less severe limiting factors. With these increases, species richness declines, suggesting that, under such conditions, a few species of lichens and bryophytes are capable of outcompeting colonizing vascular plants and producing large amounts of phytomass and high plant cover values.

Those disturbances with the greatest floristic similarity to the controls also had the greatest plant cover and above-ground phytomass. This suggests that either the initial disturbances were slight or that local plant species were the most important colonizers. The major floristic change indicated by the low similarity coefficients was produced as a result of a change from a lichen to a vascular plant-dominated plant community and supports the latter approach.

Relatively low values of species richness correspond with high similarity coefficients and the reverse is also true. This suggests that the number of species common to both the control and disturbed site floras may remain constant from one disturbance to the next, with increases in species richness resulting from invasion by

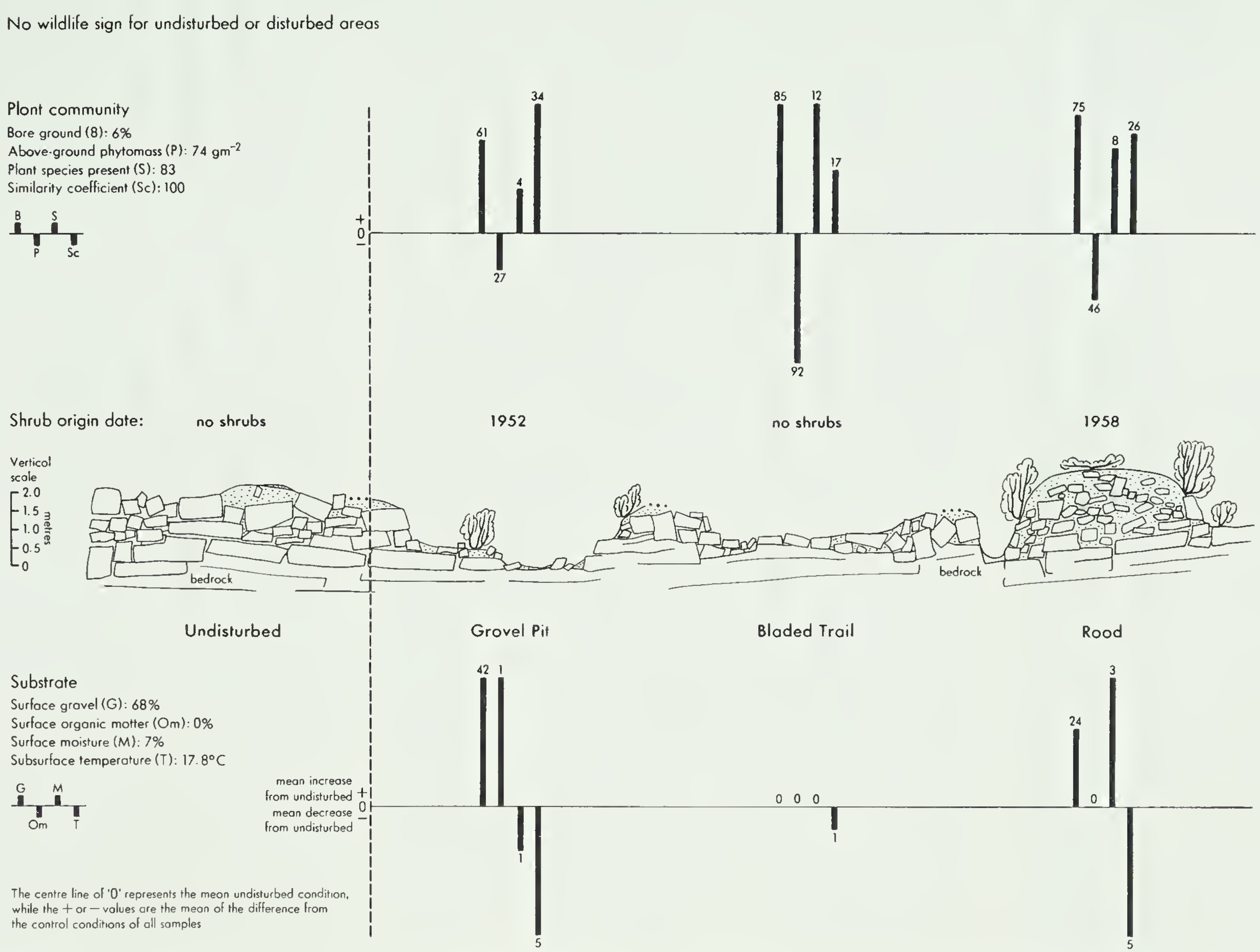


Figure 6.7 Idealized section with selected ecological characteristics of CANOL Project disturbances in Crustose Lichen Tundra, N.W.T.

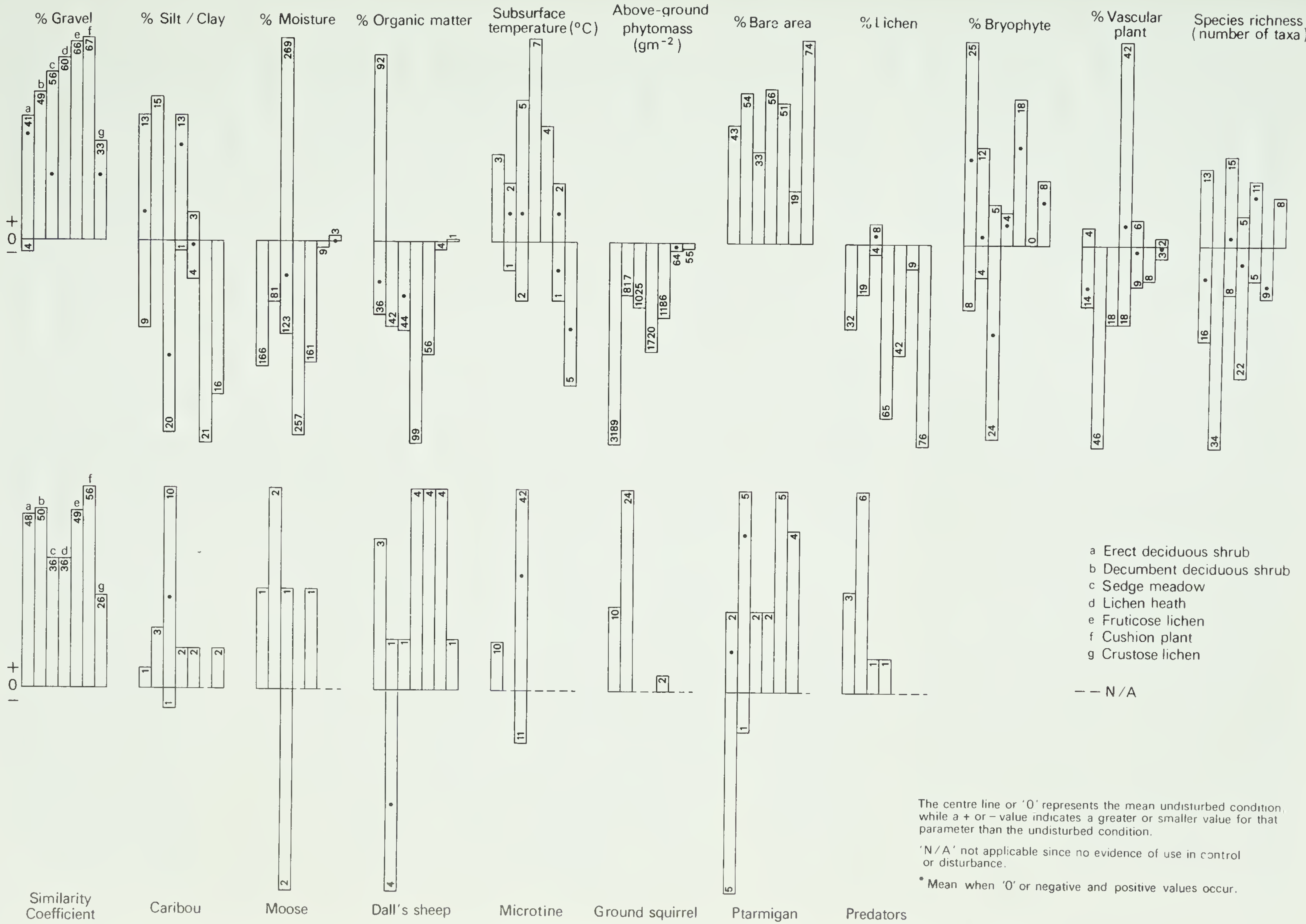
species from outside of the control community. The presence of vascular plants on disturbances constitutes a significant change in the vegetation. These vascular plants provide resident wildlife with a type of forage not otherwise available in this plant community.

6.2.8 Summary

Figure 6.8 compares the average control–corrected values for each of the major substrate, botanical and wildlife parameters among the seven plant communities. When relevant, both mean increases and decreases relative to the control values are plotted, showing the average level of variation.

With only one exception, gravel content was higher than that of the controls on all disturbance types in all communities, and with two exceptions, organic and moisture content were consistently lower on disturbances than on control sites (Figure 6.8). The coarser substrates of disturbances are the result of the burial or removal of surface organics and have produced drier and warmer environments. Cushion Plant Tundra showed the greatest deviations from undisturbed conditions in gravel and sand–silt/clay content but were among the most similar to controls with respect to organic content, moisture content and subsurface temperature (Figure 6.8) which was to be expected, since control soils were Regosols. Disturbances in Crustose Lichen Tundra had the smallest differences from control values for three substrate parameters since these plant communities occupy blockfields which have some characteristics in common with disturbances.

Cushion Plant Tundra and Crustose Lichen Tundra showed little difference in moss and vascular plant cover values between disturbed and control sites. These two plant communities had coarse, stoney, Regosolic soils that were very similar to those of the disturbances in other types of tundra where the finer surface materials and organics had generally been removed or buried. However, Lichen Heath Tundra showed relatively large differences from control conditions for four substrate parameters. Disturbed substrates in this type of tundra were least similar to those of the controls since they experienced the greatest reductions in organic matter which in turn allowed the substrates to dry out and become warmer than their associated controls (Figure 6.8).



The centre line or '0' represents the mean undisturbed condition, while a + or − value indicates a greater or smaller value for that parameter than the undisturbed condition.

'N/A' not applicable since no evidence of use in control or disturbance.

* Mean when '0' or negative and positive values occur.

Figure 6.8: Long-term ecological responses to ALL CANOL DISTURBANCES in EACH PHYSIOGNOMIC PLANT COMMUNITY

As a consequence of substrate characteristics that were substantially different from those found under control conditions, all types of disturbances in all plant communities had more bare ground than was found on control stands. Above-ground phytomass was consequently lower in disturbed areas (Figure 6.8). Lichen cover values were also lower on disturbances, with the exception of Sedge Meadow Tundra where they were virtually lacking in the controls. The short time interval since the initial disturbance may also be an important contributing factor. Based on the presence of much older shrubs in control stands (e.g. 165 years old), it may be too soon to determine if recovery will proceed to reestablish conditions more similar to those of the control stands.

Disturbance plant communities in Decumbent Shrub Tundra and Crustose Lichen Tundra were most different from their control stands (Figure 6.8). Decumbent Shrub Tundra had the greatest reduction in species richness but sites in this plant community also had some of the highest floristic similarity values with their control plant communities, indicating that local species were well adapted to colonizing disturbances. Disturbances in Crustose Lichen Tundra also showed increases in species richness relative to control values but had the lowest average similarity coefficient, indicating that in this plant community, even the small differences in substrate characteristics between disturbances and control stands favoured the introduction of 'new' species rather than revegetation by those found in undisturbed areas. This is an environment where slight substrate changes can result in substantial plant community alterations. Botanical differences in Cushion Plant Tundra were slight when compared to those in the other tundra types and disturbance substrates also were most similar to those in the control stands. This does not reflect a lack of disturbance. Roads and gravel pits were constructed here as in other plant communities. However, control characteristics are very similar to those of the disturbed sites in this area.

Results of this study indicate that use of the area by resident wildlife has changed in response to changes in ground surface and plant community characteristics. wildlife data show much higher levels of use on disturbed sites than in control areas in all plant communities (Figure 6.8). Because of its widespread distribution, it seems probable that Erect Deciduous Shrub Tundra was the only community with sign of all of the major

species and/or animal groups. Disturbances in Decumbent Shrub Tundra showed some of the largest differences in wildlife use from control conditions. Variations from controls were slight in Crustose Lichen Tundra. Woodland caribou and Dall's sheep were the only animals found in that community.

It is evident that disturbances initiated 34–36 years ago have produced unique ecological responses in each of the seven plant communities studied. On the basis of the analysis presented in this chapter, Crustose Lichen Tundra has sustained the lowest degree of alteration in the long-term. Despite a relatively high similarity between control and disturbed substrates, Decumbent Shrub Tundra appears to have experienced the greatest overall change with respect to botanical and wildlife characteristics and therefore was most altered by the CANOL disturbances.

6.3 Conclusions

The ecological characteristics of disturbances vary among the seven tundra plant communities studied and are not static. It appears that natural ecosystem rehabilitation is continuing, although it is not necessarily directed towards the recovery of predisturbance conditions. Most disturbance systems increase environmental diversity within otherwise homogeneous areas. CANOL disturbances have effected environmental changes that can be viewed as negative or positive, depending on the perspective taken. Despite the compositional and structural simplification of many plant communities, there are few cases where habitat improvement for resident wildlife has not resulted. These ecological conditions have developed after 34–36 years of abandonment and would not have existed shortly after the termination of the CANOL Project.

7. A discussion of the Implications of CANOL Project Disturbance Studies to Future Northern Developments

7.1 Introduction

Previous discussions have demonstrated that even some minor types of human use of tundra areas can result in environmental alterations and in long-term environmental change. It is commonly assumed that disturbances cause undesirable changes and this may well be true in an aesthetic sense. However, it is difficult, and sometimes perhaps impossible to determine when the overall impact of a disturbance is positive or negative in a particular ecosystem. For example, if the introduction of a new species onto disturbances coincides with the extinction of local plant species, has the overall impact been positive or negative? Regardless of the type of disturbance both positive and negative impacts will usually occur and since the importance of various factors will be weighted differently by different people, one cannot simply compile a balance sheet and treat all ecosystem components as equal.

Earlier chapters have evaluated substrate, botanical and wildlife components of CANOL disturbances and in some cases it can be concluded that the net long-term effect has been negative (e.g. oil spills in most plant communities) or positive (e.g. bulldozer tracks in Fruticose Lichen Tundra or gravel pits in Sedge Meadow Tundra). Natural disturbances in northern environments provide habitat for many resident wildlife species. For example, moose select river bottom locations where preferred forage is available on the annually disturbed flood plain (Wolff and Cowling 1981; Wolff and Zasada 1979). This illustrates that the 'edge' created where a man-induced or natural disturbance passes through an otherwise homogeneous landscape can be an area of concentrated biological activity. The flush of growth noted on burned areas (Wien 1974) and in areas where river silting occurs (Gill 1973) is a response to the release of nutrients and the initial lack of competition for resources such as light and water. Current conditions associated with the CANOL Project indicate that wildlife use of these disturbances is greater than that of undisturbed sites, that floristic diversity can increase after disturbance, that surface temperatures now are generally warmer, etc. Findings such as these support the statement that man-induced disturbances can be similar to natural ecosystem

disturbances.

As no effort was made to rehabilitate CANOL disturbances, it is important to note the nature of these ecological responses after only 34–36 years. Man–induced disturbances can modify existing environmental conditions so that plant productivity is enhanced, so that the growth of forage species preferred by resident herbivores is favoured and so that unencumbered travel–ways are provided for large mammals. If disturbances are managed bearing their long–term evolution in mind, existing ecological units, such as plant communities, could be modified to increase their biological contribution. Man–induced disturbances in relatively sterile environments can improve the area's contribution to the ecosystem by providing less limiting environments for plants, increasing floristic diversity, causing a species shift to preferred forage species that become established, etc. The CANOL Project disturbances, after 34–36 years of unassisted recovery provide examples of these types of changes. However, there are also examples of alterations of substrate parameters resulting in more limiting environments, reductions in the number of plant species and the removal of plants that would otherwise provide forage for resident wildlife. If steps had been taken to enhance rehabilitation by producing less limiting substrates it is probable that revegetation rates would have been faster. By employing appropriate rehabilitation techniques, with sufficient understanding of these ecosystems, it is conceivable that the positive aspects of recovery would have been greater. The fact that unassisted natural recovery proceeds to positive ecological responses suggests that disturbances can and should be managed to produce ecosystem enhancement.

CANOL disturbances were generally linear and therefore affected only a small part of each ecological unit that they passed through. Consequently, they have very large perimeter to area ratios and the opportunities for short distance dispersal by plant disseminules are almost unlimited. In addition, plants propogating by stolons and rhizomes can encroach from the disturbance edge. Disturbances that would affect large areas and/or perhaps completely eliminate the ecological units within their borders (e.g. open pit mines, hydroelectric dams, large hydrocarbon spills, extensive tailings dumps) would probably have much different effects and overall would probably be a negative ecosystem alteration in the long term.

A major concern for environmental managers and ecologists involved in development planning should be the evaluation of the significance of all components of the ecosystem for the perpetuation and maintenance of the system. The relative importance of all ecosystem components will vary from one area to the next and an attempt should be made to determine which factors contribute most significantly to the maintenance of a particular ecosystem and how these will be affected by the development. Then, when faced with the choice of locating facilities, informed decisions can be made as to where to concentrate development by selecting those areas that are most capable of sustaining environmental impacts.

Such decisions can be made only with a detailed understanding of the ecosystem to be affected. This is certainly the most difficult aspect of the problem since little agreement exists as to what ecosystem parameters are most important or the level of information that is needed. Data for the key parameters considered in this study of CANOL disturbances (Chapters 3,4 and 5) are readily derived using commonly applied methods and could therefore be practically compiled for areas to be developed.

Man–induced or natural terrain disturbances in tundra areas are essentially permanent features on the landscape. For example, in the Macmillan Pass area there is a discernible difference between the last occupied channels and adjacent areas on outwash fans. These features are remnants of the most recent glacial retreat and are possibly 6,000 to 10,000 years old. In the High Arctic, 1,000 year–old Inuit camps can be relocated with relative ease and these sites may have been used for only a short period of time (Schledermann 1977). In the Burwash Uplands of the Yukon, cart tracks initiated in the late 1800's remain evident (Lore 1977). In many ways, CANOL disturbances were similar. They have created topographic alterations in an environment where minor morphological differences produce significant microclimatic variations. They have created radically different substrates in an area where minor changes in such things as organic layer thickness, moisture content and subsurface temperatures produce dramatic plant community differences over short distances. Many of these changes appear to be essentially permanent. These examples of seemingly minor disturbances have significantly altered the local environment to the extent that their ecological characteristics remain different from the adjacent, undisturbed areas.

The long-term evolution of some initially minor disturbances has increased the impact and/or the area affected. Examples from the CANOL Project include the abiotic effects of rerouting surface drainage ways and increasing thermal erosion and the biotic effects of creating niches for *Salix* species and arctic ground squirrels. The speed of change and subsequent degree of alteration varies with the type of disturbance and the nature of the area affected.

The ecological contribution of each altered site varies with the type of disturbance and the plant community affected. All provide habitats for resident plants and animals but in the less productive regions, disturbances appear to resemble the undisturbed condition more closely than in areas with complex plant community structure and greater standing crop. This is not to say that developments should always be placed in less productive areas. Even though disturbed conditions in more productive areas are further from those of associated control areas, their total ecosystem contribution may be still greater than that of the less productive undisturbed areas. Developments must be planned considering both temporal and spatial consequences. If recovery in more productive areas is predicted to be more rapid, the short-term consquences of disturbances may not be as significant when considered in the longer time frame. The disturbance of a given area will have a much greater impact on a system of limited extent than on a more widespread one. The areas that are necessary to the maintenance of resident wildlife should be identified and avoided whenever possible when choosing routes or site locations. These would include 'critical' habitats such as mineral licks, calving grounds and over-wintering areas. The ranking system should include information on biological productivity, sensitivity to disturbance and potential for rapid, natural rehabilitation. However, this type of analysis requires detailed information on the characteristics and distribution of landscape units in the development area.

In some ways, the ecological effects of these human disturbances differ little from those of naturally occurring disturbances. Along the CANOL route, recent mudflows that extend into valley bottoms, inundating and destroying established plant cover, do not differ substantially from the CANOL road bed in their ecological characteristics. Even oil spills have their naturally occurring equivalent and studies of oil seeps have contributed to rehabilitation efforts on man-induced spills (Alexander and Benoit 1972). In the CANOL

Project study area, river bars are similar to gravel pits and have similar plant species and cover characteristics while abandoned game trails resemble vehicle tracks in their ecological characteristics. The main difference between natural and man–induced disturbances lies in their initiation rather than their subsequent ecological characteristics.

Aesthetically however, there may be a great difference as man–induced disturbances often take regular and symmetrical shapes. The straight lines of a road, trail or track contrast sharply with the irregular, curving lines of river channels, lake margins, etc. Also, man–induced disturbances can transect natural borders to form sharp constrasts whereas natural disturbances may have transition zones that represent a gradual change along a gradient. Of course there are numerous exceptions to this such as are seen along steeply cut river banks, on the border of fire scars, or at the termination of debris slopes. Generally, excepting cases such as oil spills, the long–term difference between natural and man–induced disturbances lies not in their ecological characteristics but rather in the sharp definition of the latter in a landscape of irregular patterns and can result in positive ecological changes (Douglass 1977; Lore 1977).

A significant difference between natural and man–induced disturbances is that the location of the latter are controlled. Conscious decisions are made to select routes and sites for development and careful choices can minimize the level of negative impacts in existing ecosystems.

7.2 Implications For Northern Development

Most developments occur in several stages or phases. This discussion will include implications of the CANOL Project relevant to the 1) preplanning and exploration; 2) construction and development; 3) operation and abandonment; and 4) abandonment phases involved with most northern developments. These phases are somewhat arbitrary since they usually overlap in time as was the case with the CANOL Project (Table 2.5). Furthermore, they can also be spatially inseparable. The recovery on CANOL disturbances provides more material for discussion of the abandonment phase of a project and stress will therefore be placed on this section with a few relevant comments for each of the other phases.

The rigours of the northern environment and its slow rate of recovery make any errors in the history of development projects potentially costly in both economic and environmental terms. For example, if sufficient preplanning had been carried out for the CANOL Project, at least 115 km of bladed trails and bulldozer tracks in the Northwest Territories as well as 150 km of roads would not have been constructed. These unnecessary disturbances, particularly those associated with the roads, were extensive, environmentally disruptive and economically costly. With adequate preplanning they could have been avoided.

Total ecosystem impact can be reduced by disturbing only sites that have low susceptibility to disturbance and/or will respond well in the long-term. For example, bladed trails created during the CANOL Project were less disruptive in Decumbent Shrub Tundra than in Lichen Heath Tundra (Section 6.2) and where possible, such disturbances should avoid these relatively sensitive communities. Unfortunately, the location of a resource is often independent of terrestrial ecosystem characteristics and sites for development often are found in ecologically sensitive areas. Intelligent development decisions are possible only if the resource planner has baseline information for each land unit and detailed large scale maps.

Exploration and survey practices that were common with the CANOL Project have not changed substantially over the past 40 years. The exploration phase of development still results in extensive terrain disturbance. Pits are excavated to determine the nature of surficial deposits; drilling operations are conducted from tracked vehicles that in some cases move across the terrain in any season; temporary camps are established at convenient locations, etc.

Most ground surveying for CANOL was carried out during the winter and these disturbances were much less disruptive than were those created during other seasons. For example it is difficult to relocate sections of the original winter tractor survey trail. Such operations, covering large areas and involving heavy machinery, should therefore be completed during the winter whenever possible.

During the construction phase, temporary facilities such as fuel caches, work camps, storage areas, etc. may be necessary. These require land and if properly planned such areas can later be used for permanent facilities. For example, the original winter

road access to the site may become the route for the power line or the final year-round access road. The Canol Road was built over much of the original survey route following the completion of the pipeline. Where this practice was not followed, it is possible to discern an additional right-of-way in those areas where operations were conducted during the thaw season. Sequential land use would minimize the amount of disturbed area and could prove much less costly. If this practice is followed, initial decisions regarding site selection become much more important.

CANOL Project construction of most types was completed during the winter. Where winter and summer construction facilities can be compared, it is evident that operations carried out during the growing season have been the most disruptive. In Erect Deciduous Shrub Tundra, winter work will damage the tall shrub canopy but in other plant communities, where snow cover is sufficient, surface disturbances will be minimized. Even in areas with a thin and discontinuous snowpack, vehicular disruptions of the frozen surface layers will have less impact than if the ground were thawed. Surface disruption is reduced on frozen ground and dormant plants appear to be less easily damaged than are those that are actively growing (Hernandez 1973; Kerfoot 1972; Lambert 1972). During the thaw season, it is essential that all operations be restricted to areas that are actually under construction or will be disturbed in the future. Use of areas that will not sustain future development should be minimized since even a minor disturbance such as the CANOL Project bulldozer tracks can be essentially permanent even though the changes are far less than more distructive types of disturbances.

It has been noted in previous discussions that the operation of CANOL No.1 lasted only 13 months and that this limited time interval probably helped to minimize the ecological impacts on wildlife during the life of the Project. For example, the road traffic or pump station noise would have affected only a portion of the lives of most of the resident wildlife. However, if pump station noise had affected generations of resident animals such as Dall's sheep, they might well have shifted their range to avoid these areas. If this resulted in the loss of critical or preferred habitat then populations would suffer. In addition, harrassment and hunting pressures might have been greater. Activities during the life of the CANOL Project therefore had little effect on wildlife as a direct consequence of the construction and operation phases. However, this was not the case

during the 34–36 years of abandonment.

The CANOL Project is located in an extremely limiting environment. Climatic conditions such as temperature extremes on a daily, seasonal and annual basis caused many operational problems including pipeline creep, accelerated rates of metal fatigue and consequent mechanical breakage, severe outdoor working conditions, etc. Under these restrictions and with inadequate technical information to make adjustment to these conditions, a number of unnecessary disturbances resulted. The most severe of these were caused by oil spills. Although small in area, these sites appear to be little modified by natural processes after 34 to 36 years. However, perhaps more importantly, the extent of their impact was not limited to these localized sites. For example, vehicles used to convey men and materials to the pipeline break often caused terrain disturbances such as bladed trails and bulldozer tracks.

Hemstock (1945) suggested several reasons why these spills were so large. A number of these were directly related to the extreme climatic conditions (Section 2.3.5.2). For example, winter spills beneath the snow were hard to locate, stockpiled pipe was hard to get at beneath the snow and conditions of travel and work were very restrictive for men and machinery. These limitations have not changed greatly to the present day. The circumstances, though not necessarily the causes surrounding the Rainbow Lake Pipeline spills in north–central Alberta since the early 1970's were very similar with the exception that, in addition, the pipeline was buried. Over the past 34–36 years, there has been an increase in appreciation of the necessity to clean up after a spill occurs and to follow this with mitigation measures such as scarification and fertilizer applications (Johnson 1981, McKendrick and Mitchell 1978). The CANOL spills, although ecologically devastating and long–lasting, are small and very localized. The negative impacts associated with moving men and materials through these ecosystems to rehabilitate such small areas could far outweigh the positive effects gained. Consequently, land use officers will have to determine whether or not the terrain disruptions incurred during clean–up measures counterbalance any potential improvement of the spill conditions. Such small spills would probably be better left, unless helicopters could be used to transport men and equipment for cleanup programmes and the high cost of such an operation would probably eliminate it as an alternative in most cases. The

cleanup of spilled oil and other toxic substances needs to be treated on an individual basis. However, in all cases, decisions should include careful consideration of the ecological consequences of the associated activities necessary to support such programmes.

Generally, the abandonment phase causes little terrain disruption, unless a salvage operation such as occurred with the CANOL Project, is undertaken. The effect of salvage activities removing equipment and other resaleable items can be similar to that of prolonging the period of operation. For example, the CANOL No. 1 pipeline system was abandoned with over 60,000 bbls of crude oil in the line. During the salvage operations, some of this was used. However, much was spilled. Salvage operations conducted during the thaw season will redisturb some areas, and as with the exploration and construction phases, winter activity would probably produce the least environmental disruption.

The Territorial Land Use Regulations (1977) define provisions concerning the restoration of areas that have had Land Use Permits. The regulations state that

> "after completion of a land use operation, [the permit holder must] restore the permit area as nearly as possible to the same condition as it was prior to commencement of the land use operation"

This implies that l) it is possible to restore the area to a pre-disturbance state and 2) this is desirable. Based on the CANOL Project disturbance studies, the first point appears to be unachievable, except possibly over an extremely long period of time. The time necessary for ecological recovery to proceed to acceptable levels will vary with the type of disturbance and the environment affected. No time limit is placed on this requirement (Land Use Regulations 1977). The fact that CANOL disturbances are still readily discernible from their controls suggests that this is unachievable within realistic or effective time limits.

The rationale behind the second point can also be questioned. This study shows that it may be possible to effect some types of environmental enhancement through restoration programmes, producing dramatic differences between disturbed and undisturbed plant communities. Since complete restoration is probably impossible, the goal of resoration programmes should be to bring the disturbance into a biologically productive status within the shortest period of time. Native plants growing locally should

be used in revegetation programmes whenever possible because these species will be pre-adapted to each area's environment and may also be preferred forage for resident herbivores. Furthermore, many native species will require little or no site preparation prior to their introduction and little if any additional support in subsequent years.

Results presented in Chapter 4 can aid in the selection of species capable of colonizing disturbances in a variety of different terrain types. It has also been shown that the best colonizers often are not the dominant plants in the undisturbed areas and in many cases the most successful species are not found locally (Table 4.24).

Preceding sections have illustrated that natural recovery can proceed without human intervention, to create both positive and negative ecosystem disruptions after 34-36 years. In several plant communities affected by CANOL disturbances, rehabilitation was directly related to surface organic matter content and the amount of fine-textured particles (Chapter 6). The concentration of this material near the surface of disturbances affected substrate moisture and temperature, both of which are limiting conditions for revegetation. Such changes caused the long-term impacts of different disturbances to vary significantly with different plant communities. For example, roads were the most similar to controls in Lichen Heath Tundra but were the most dissimilar in Cushion Plant Tundra. It is therefore difficult to make broad generalizations. However, several points can be made that should be considered when examining the rehabilitation of abandoned developments as most types of terrain disturbance will probably recover more rapidly with some initial assistance. CANOL disturbance studies provide a number of examples that illustrate possible methods for stimulating relatively rapid natural rehabilitation. These include the following points:

1. Organic matter and topsoil should be stockpiled during construction and later spread on abandoned disturbances. A comparison of revegetation rates on bladed trails and on other disturbances in which surface layers had been removed (Table 3.10) illustrates the need to retain existing organic matter whenever possible. In addition, dormant seeds of native plants, contained in this material, may germinate to initiate a more rapid rate of plant colonization. Mulches produced from straw or wood chips might enhance substrate characteristics but would not provide this further advantage. However, in Cushion Plant Tundra and Crustose Lichen Tundra,

there is little organic matter and fine particle content in control soils. Consequently, stockpiling would not be possible and most disturbances were found to enhance moisture content initially (Chapter 3).

2. The Canol Road caused excessive surface compaction and therefore lacks significant surface micro-topography. Consequently, moisture runs off and roots cannot penetrate easily. The lack of surface micro-topography produces little micro-habitat diversity. Scarification and furrowing of these surfaces would be desirable, creating micro-habitats and reducing substrate compaction. A comparison of the road with the less compacted and often highly irregular surfaces of false start roads and gravel pit access roads illustrates this (Table 3.10).

3. In most plant communities shrubs comprised a significant proportion of the phytomass on most types of disturbances and in several cases marker pegs, set during the course of this study, were found to have sprouted after one or two years. The use of shrub cuttings of *Salix alaxensis* and perhaps other species such as *Salix planifolia* could result in rapid production of biomass on disturbances. This has particular promise on sites where seed germination appears to be limited by factors other than moisture (e.g. on oil spills). In addition, *Salix* species are preferred browse by resident ungulates.

4. In addition to the shrubs, there are a number of herbaceous plants that commonly, naturally colonize disturbances, and that make a substantial contribution to the live standing crop. Several have demonstrated their ability for long-distance dispersal. Vascular plants include *Calamagrostis canadensis*, several Carices, *Dryas octopetala*, *Epilobium* spp., *Hedysarum mackenzii*, *Hierochloe alpina*, *Juncus balticus*, *Poa* spp., and *Trisetum spicatum*. Mosses in the genus *Polytrichum* and lichens in the genera *Peltigera* and *Stereocaulon* were also important. The vascular plants are commonly prolific seed producers and could provide local seed sources for native plant revegetation programmes.

5. After 34–36 years, bulldozer tracks, bladed trails, gravel pit access roads and false start roads have caused little ecological disruption in some plant communities (Chapter 6). In many cases, attempts to enhance recovery on these disturbances could serve to magnify rather than mask the initial disturbances. Initially, such

disturbances are relatively minor and/or in the long-term their ability to recover is greater. However, disturbances causing little ecological change over large areas should not be ignored since they may be extensive enough to effect significant alterations in existing ecosystems. When the entire ecosystem in an area could be directly affected by a disturbed system, careful consideration of the acceptable level of alteration should be made prior to development. Detailed pre-planning can greatly reduce the size of the area affected and aggressive revegetation programmes utilizing native species as far as is practical for seeds and cuttings can help to minimize impacts. Also, land use permits could specify the types of disturbances and maximum areas to be directly affected by each within the different plant communities in the permit area.

6. Each year along the CANOL route ungulates become caught by their antlers in wire that has come to ground following the removal or collapse of telephone poles. Where above-ground wire has the potential for ensnaring animals, it should be removed.
7. Along the CANOL, thermokarst subsidence, river erosion, solifluction, etc. have greatly modified many portions of the road, track and trail disturbances. If the projected life of such facilities is short, it could be desirable to place them in locations where they will eventually be eliminated or modified by natural geomorphological processes. Of course, short-term hazards affecting the use of the facility would have to be considered as well as the long-term characteristics of the disturbance.
8. Oil spills create severe, long-lasting ecological disturbance. The CANOL Project spills generally covered only small areas.

7.2.1 Summary

Areas affected by the CANOL Project contain many examples of disturbances that can be expected in association with large and small scale Northern development projects. Projects requiring linear corridors for tote or all-weather roads, pipelines, or power transmission lines have many similarities with the CANOL Project. However, some basic differences exist, not all of which relate to physical site characteristics. Preplanning

was sketchy to nonexistent for the CANOL Project (Sections 2.3–2.5) and no environmental impact statement was required, as would be the case today. Aerial photographic and topographic map coverage was not available in 1942 but now exists for all of northern Canada and *Land Use Information Maps* also are available for much of the Yukon and Northwest Territories. In contemporary projects, detailed site studies are conducted in the area to be affected, and sources of aggregate and final routes are selected prior to the initiation of construction. This was not the case during the CANOL Project. Although the U.S. Army and Project contractors had representatives on site that were concerned with engineering requirements, no government inspectors were present to ensure that environmental alterations were minimized. CANOL disturbances are the product of a shortlived, emergency, wartime project in which decisions were based primarily on the need for expediency, with little concern for environmental impacts.

Today, environmental protection is a major concern when applying for land use permits. Detailed studies are carried out to provide baseline information so that informed decisions can be made regarding project design and the phasing of development. Unlike the CANOL Project, these programmes include rehabilitation of disturbed areas following abandonment. Consequently, the impacts associated with similar northern developments today should be less. The overriding principal that should govern development practices in all phases is that all disturbances will be essentially permanent. If the objective is to cause as little environmental change as possible, disturbances should be minimized in extent and severity.

Selected References

Agriculture Canada. 1976. Glossary of terms in soil science. *Agriculture Canada Publication* 1459. Ottawa.

Aitken, J.D. and Cook, D.G. 1974. Carcajou Canyon map-area, District of Mackenzie, Northwest Territories, *Geological Survey of Canada, Paper* 74-13, Ottawa.

Anonymous. 1970. *Description of Canol Project in abandoned state.* Construction Engineering Unit Canadian Department National Defence, Yellowknife.

Anonymous. 1980. The Aleutians, World War II. *Alaska Geographic* 7(3): 130-161.

Argus, G.W. 1973. The genus *Salix* in Alaska and the Yukon. *Publications In Botany No. 2.* National Museums of Canada, Ottawa.

Atlas, R.M. and Brown, J. 1978. Introduction to the workshop on ecological effects of hydrocarbon spills in Alaska. *Arctic*, 31(3): 155-157.

Babb, T.A. 1973. High arctic disturbance studies In Botanical studies of man-modified habitats in the Mackenzie Valley, Eastern Mackenzie Delta Region and the Arctic Islands. L.C. Bliss and R.W.Wein eds. *ALUR* 72-73-14:150-162.

Babb, T.A. 1972. High Arctic disturbance studies. In Botanical studies of natural and man modified habitats in the Eastern Mackenzie Delta Region of the Arctic Islands. L.C. Bliss and R.W. Wein eds. *ALUR* 71-72-14:230-281.

Babb, T.A. and Bliss, L.C. 1974. Effects of physical disturbance on Arctic vegetation in the Queen Elizabeth Islands. *Journal of Applied Ecology*, 11:549-562.

Banfield, A.W.F. 1977. *The Mammals of Canada*. National Museums of Canada, University of Toronto Press, Toronto.

Bird, C.D. 1974a. Botanical studies near the Mackenzie River, Northwest Territories. *Geological Survey of Canada, Open File* 225, Ottawa.

Bird, C.D. 1974b. Botanical studies in the Yukon and Northwest Territories carried out in 1972 in connection with Geological Survey of Canada field parties run by Dr. O. Hughes and Dr. N. Rutter. *Geological Survey of Canada, Open File* 227, Ottawa.

Blanchet, G.H. 1942. *Excerpts, Personal Diary of Guy Blanchet, Norman Wells to Sheldon Lake - 1942 (Oct 13 Nov 26).* Finnie Collection, Belvedere.

Blanchet, G.H. 1943. *Report on the Operations of the Canol Project During the Past Year as Affecting the Location and Survey of the Pipeline From Canol to Whitehorse and Reconnaissance Trips, Fort McPherson to Lapierre House, and Fairbanks to*

Tanana. J. Gordon Turnbull and Sverdrup and Parcel, Edmonton. Finnie Collection, Belvedere.

Blanchet, G.H. 1944. The Canol Project. *Canadian Surveyor* 8(5):2–7.

Bliss, L.C. 1979. Vegetation and revegetation within permafrost terrain. In *Third International Permafrost Conference on Permafrost, Proceedings Volume* 2, National Research Council of Canada, Ottawa, 31–50.

Bliss, L.C. and Wein, R.W. 1972. Plant community responses to disturbances in the western Canadian Arctic. *Canadian Journal of Botany* 50:1097–1109.

Bliss, L.C. and Wein, R.W. eds. 1972. Botanical studies of natural and man-modified habitats in the Eastern Mackenzie delta region and the Arctic Islands. *ALUR* 71–72–14, Department of Indian Affairs and Northern Development, Ottawa.

Blusson, S.L. 1971. Sekwi Mountain Map-area, Yukon Territory and District of Mackenzie (105P), Ottawa. *Geological Survey of Canada, Paper* 71–22.

Blusson, S.L. 1974. Niddery Lake Map-area (106A). *Geological Survey of Canada, Open File* 205, Ottawa.

Brassard, G.R. 1972. Mosses from the Mackenzie Mountains, Northwest Territories. *Arctic* 25(4):308.

Brown, J. and Berg, R.L. (ed) 1980. Environmental engineering and ecological baseline investigations along the Yukon River–Prudhoe Bay Haul Road. *CRREL Report* 80–19, Hanover.

Burns, B.M. 1973. The climate of the Mackenzie Valley – Beaufort Sea, Volume I. *Climatological Studies, Number* 24, Atmospheric Environment, Toronto.

Cairns, A.L. and Telfer, E.S. 1980. Habitat use by 4 sympatric ungulates in boreal mixedwood forest. *Journal of Wildlife Management*, 44(4):849–857.

Cody, W.J. and Acton, D. 1973a. *Cirque Lake CCIBP/CT Region* 10, *Site Number* 55. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Acton, D. 1973b. *Florence Lake CCIBP/CT Region* 10, *Site Number* 31. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Acton, D. 1973c. *Coral Peaks CCIBP/CT Region* 10, *Site Number* 59. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Acton, D. 1973d. *Sculpin Springs CCIBP/CT Region* 10, *Site Number* 70. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Acton, D. 1973e. *Toitye Hot Springs, CCIBP/CT Region* 10, *Site Number*

71. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Acton, D. 1973f. *Carcajou Lake CCIBP/CT Region* 10, *Site Number* 72. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Acton, D. 1973g. *Mirror Lake CCIBP/CT Region* 10, *Site Number* 74. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Acton, D. 1973h. *Caribou Flats CCIBP/CT Region* 10, *Site Number* 76. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Day, J.H. 1971. *Plains of Abraham CCIBP/CT Region* 10, *Site Number* 26. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Sneddon, J.I. 1972. *Mackenzie Mountain Barrens CCIBP/CT Region* 10, *Site Number* 58. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Sneddon, J.I. 1973a. *Raven's Throat CCIBP/CT Region* 10, *Site Number* 29. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Sneddon, J.I. 1973b. *Moosehorn Headwaters CCIBP/CT Region* 10, *Site Number* 57. Canadian Committee for the International Biological Programme, Edmonton.

Cody, W.J. and Sneddon, J.I. 1973c. *Lymnaea Springs CCIBP/CT Region* 10, *Site Number* 60. Canadian Committee for the International Biological Programme, Edmonton.

Collins, W.B. and Urness, P.J. 1979. Elk pellet group distributions and rates of deposition in aspen and lodgepole pine habitats. In M.S. Boyce and L.D. Haydon-Wing, *North American Elk:Ecology, Behavior and Management*. The University of Wyoming, Laramie, 140-144.

Cruikshank, J. 1974. *Through the Eyes of Strangers: A Preliminary Survey of Land Use History in the Yukon During the Late Nineteenth Century*. Yukon Territorial Government and the Yukon Archives, Whitehorse.

Crum, H.A., Steere, W.C. and Anderson, L.E. 1973. A new list of mosses of North Americal North of Mexico. *Bryologist* 76(1):85-130.

DIAND. 1977. *Procedures, Licensing, Leglislation and All That*. DIAND, Ottawa.

DIAND. 1981. *A Guide to Territorial Land Use Regulations*. DIAND, Ottawa.

Dansereau, P. 1971. Dimensions of environmental quality. *Sarracenia* 14.

Douglass, R.J. 1977. Effects of a winter road on small mammals. *Journal of Applied*

Ecology 14:827–834.

Druzhinina, O.A. and Zharkova, Y.G. 1979. A study of plant communities in anthropogenic habitats in the area of the Vorkuta Industrial Centre. In The effect of disturbance on plant communities in tundra regions of the Soviet Union. *Biological Papers, University of Alaska* No. 20:30–53.

Ebbutt, F. 1931. The Gravel River Indians. *The Canadian Geographical Journal* 2(4):311–321.

Everett, K.R. 1978. Soils and their reaction to impact and hydrocarbon spills. In D.E. Lawson and others, *Tundra Disturbances and Recovery Following the 1949 Exploratory Drilling, Fish Creek, Northern Alaska, CRREL Report* 78–28:25–40.

Finnie, R.S. 1942a. *Fort Norman to Whitehorse, The First Reconnaissance Flight, 13 June 1942.* Edmonton. Finnie Collection, Belvedere.

Finnie, R.S. 1942b. A route to Alaska through the Northwest Territories. *Geographical Review* 32:403–416.

Finnie, R.S. 1943a. U.S. Army taps Canadian oil for Alaskan-based operations. *World Petroleum* 14:32–36.

Finnie, R.S. 1943b. Canol blitz. *Maclean's Magazine* August 15:12–13,37,40–42.

Finnie, R.S. 1945a. *The Canol Project.* Yukon Archives, Whitehorse.

Finnie, R.S. 1945b. *CANOL, the Sub-Arctic Pipeline and Refinery Project Constructed by BechtelPrice-Callahan for the Corps of Engineers, U.S. Army 1942-44.* San Francisco.

Finnie, R.S. 1947a. *The CANOL Adventure.* Unpublished manuscript, Finnie Collection, Belvedere.

Finnie, R.S. 1947b. The epic of Canol. *Canadian Geographical Journal* 34:137–139.

Finnie, R.S. 1948. *Canada Moves North* (revised edition). MacMillan Co. Canada Ltd., Toronto.

Finnie, R.S. 1959. The evolution of Canol. *Polar Notes* 1:28–35.

Flood, M.J. 1946. *Arctic Journal and Other Works.* Wetzel Publishing Company, Los Angeles.

Franklin, J.F., Dyrness, C.T. and Moir, W.H. 1970. A reconnaissance method for forest site classification. *Shinrin Richi* 12:1–14.

French, H.M. 1974. Geomorphological processes and terrain sensitivity, Banks Island, District of Franklin. *Geological Survey of Canada Paper* 74-1, Pt A:263-266.

French, H.M. 1975. Man-induced thermokarst, Sachs Harbour airstrip, Banks Island, Northwest Territories. *Canadian Journal of Earth Sciences* 12(2):132-144.

French, H.M. 1976. Geomorphological process and terrain disturbance studies, Banks Island, District of Franklin. *Geological Survey of Canada Paper* 76-1A:289-292.

French, H.M. 1978. Terrain and environmental problems of Canadian arctic oil and gas exploration. *Musk-ox* 21:11-17.

Fuller, W.A., Martell, A.M., Smith, R.F.C. and Speller, S.W. 1977. Biology and secondary production of *Dicrostonyx groenlandicus* on Truelove Lowland. In *Truelove Lowland, Devon Island, Canada: A High Arctic Ecosystem.* L.C. Bliss ed. The University of Alberta Press, Edmonton, 437-459.

Gauch, H.G. 1979. *COMPCLUS - A FORTRAN Program for Rapid Initial Clustering of Large Data Sets.* Ecology and Systematics, Cornell University, Ithaca.

Gee, D.H. 1945. The Mackenzie River mapping project. *Surveying and Mapping* 5(3):53.

Gill, D. 1973. Modification of northern alluvial habitats by river development. *The Canadian Geographer* 17(2):138-153.

Gill, D. 1976. *Physical Environment; Environmental Report On The Macmillan Tungsten Property.* Environmental Services Group, AMAX Northwest Mining Co. Ltd., Vancouver, 39-76.

Gill, D. 1978. *Large Mammals of the Macmillan Pass Area, Northwest Territories and Yukon.* AMAX Northwest Mining Company, Ltd., Vancouver.

Godfrey, W.E. 1966. The birds of Canada. *National Museums of Canada, Bulletin No. 203.* Ottawa.

Grafe, P. 1943. *Canol No. 1, General Plan of Operations.* Yukon Archives, Whitehorse.

Gray, E. 1970. Norman Wells and the Canol Project. *The Great Canadian Oil Patch.* MacLean-Hunter, Toronto, 78-95.

Greller, A.M. 1974. Vegetation of roadcut slopes in the tundra of Rocky Mountain National Park, Colorado. *Biological Conservation* 6(2):84-93.

Greller, A.M., Goldstein, M. and Marcus, L. 1974. Snowmobile impact on three alpine tundra plant communities. *Environmental Conservation* 1(2):101-110.

Haag, R.W. and Bliss, L.C. 1974. Energy budget changes following surface disturbance to upland-tundra. *Journal of Applied Ecology* 11:355-374.

Hale, M.E. 1974. *The Biology of Lichens (2nd edition)*. Edward Arnold. London.

Hale, M.E. and Culberson, W.L. 1970. A fourth checklist of the lichens of the continental United States and Canada. *Bryologist* 73:499–543.

Hanley, P.T., Hughes, O.L., Hodgson, D.A., Pilon, J., Lawrence, D.E. and Kurfurst, P.J. 1973. Terrain maps – Mackenzie Valley (96C,D and E, 106H). *Geological Survey of Canada, Open File* 155, Ottawa.

Hara, H.S. 1980. The Hare Indians and their world. *National Museum of Man, Mercury Series, Canadian Ethnology Service, Paper* No. 63. National Museums of Canada, Ottawa.

Harbottle, J.C. and Credeur, F.G. 1966. *Woman in the Bush*. Pelican Publishing Co. San Francisco.

Hardy, R.M. and Associates Ltd. 1971. *Report on Investigations of Permafrost Degradation in Previously Disturbed Areas for Northwest Project Study Group*. R.M. Hardy and Associates Ltd., Edmonton.

Hardy, R.M. and Associates Ltd. 1972. *Report on Canol Road Study 1971 for Northwest Project Study Group, Volumes 1 and 2*. R.M. Hardy and Associates Ltd., Edmonton.

Harris, E.A. 1945. Canol, the war's epic blunder. *The Nation*. May 5, 160:513–514.

Hemstock, R.A. 1945. *Report of Operations On the Canol No. 1 Pipeline, Northwest Territories and Yukon*. Imperial Oil Limited–Norman Exploration, Hemstock collection, Calgary.

Heney, C.F. 1944. *Special Inspection of the Administration of Cost-Plus-a-Fixed-Fee Contracts Composing or Relating to the Canol Project in the Northwest Service Command*. War Department Office of the Inspector General, Washington.

Hernandez, H. 1972. *Surficial Disturbance and Natural Plant Recolonization In The Tuktoyaktuk Peninsula Region, N.W.T.* unpublished MSc. thesis, The Department of Botany University of Alberta, Edmonton.

Hernandez, H. 1973a. Revegetation studies – Norman Wells, Inuvik and Tuktoyaktuk, N.W.T. and Prudoe Bay, Alaska. In Botanical studies of natural and man–induced habitats in the Mackenzie Valley, Eastern Mackenzie Delta Region and the Arctic islands. L.C. Bliss and R.W. Wein eds. *ALUR* 72–73–14:77–149.

Hernandez, H. 1973. Natural plant recolonization of surficial disturbances, Tuktoyaktuk Peninsula region, Northwest Territories. *Canadian Journal of Botany* 51(11):2177–2196.

Hill, N., Freedman, B. and Svoboda, J. 1980. Seed banks and seedling floras in a variety of plant communities. *Ecology of a High Arctic Lowland Oasis, Alexandra Fjord, Ellesmere Island, N.W.T., Canada, 1980 Progress Report*. J. Svoboda and B. Freedman eds., Departments of Botany, University of Toronto and Dalhousie

University. pp. 79-92.

Hok, J.R. 1971. *Some Effects of Vehicle Operation on Alaskan Arctic Tundra.* unpublished MSc. thesis, The University of Alaska, Fairbanks.

Honsaker, J.L. 1981. *SPCSORT*. The Department of Geography, University of Alberta, Edmonton.

Hughes, O.L. 1970a. Quaternary reconnaissance, Northwest District of Mackenzie. *Geological Survey of Canada Paper* 70-1a, Ottawa.

Hughes, O.L. 1970b. Surficial geology maps, District of Mackenzie (96D and E). *Geological Survey of Canada, Open File* 26, Ottawa.

Hutchinson, T.C. and Freedman, W. 1975. The impact of crude oil spills on Arctic and sub-Arctic vegetation. In *Proceedings of the Circumpolar Conference on Northern Ecology*: 175-182. National Research Council of Canada, Ottawa.

Hutchinson, T.C. and Hellebust, J.A. 1978. Vegetational Recovery in the Canadian Arctic After Crude and Diesel Oil Spills, *ALUR* 75-76-83, Ottawa.

Hutchinson, T.C., Hellebust, J.A. and Telford, M. 1976. Oil Spill Effects On Vegetation and Soil Microfauna at Norman Wells and Tuktoyaktuk, N.W.T., *ALUR* 74-75-83, Ottawa.

Imperial Oil Limited. 1945. *Report of Operations In The Mackenzie River Basin*. Imperial Oil Limited, Norman Exploration, Norman Wells.

Imperial Oil Limited. 1977. *Background Information On Norman Wells*. Imperial Oil Limited, Norman Wells.

Jenness, D. 1977. *Indians of Canada*. 7th. edition, University of Toronto Press, Toronto.

Jobson, A., Cook, F.D. and Westlake, D.W.S. 1972. Microbial utilization of crude oil. *Applied Microbiology*. 23(6):1082-1089.

Johnson, A.W., Murray, B.M. and Murray, D.F. 1978. Floristics of the disturbances and neighbouring locales. In Tundra disturbances and recovery following the 1949 exploratory drilling, Fish Creek, Northern Alaska. Lawson and others eds. *CRREL Report* 78-28:30-40. Hanover.

Johnson, A.W., Viereck, L.A., Johnson, R.E. and Helchoir, H.R. 1966. Vegetation and flora. In *Environment of the Cape Thompson Region, Alaska*. N.J. Wilimovsky and J.N. Wolfe eds. U.S. Atomic Energy Commission, Division of Technical Information, Washington. 277-354.

Johnson, L.A. 1980. Revegetation and restoration investigations. In Environmental engineering and ecological baseline investigations along the Yukon River-Prudoe Bay haul road. J. Brown and R.L. Berg eds. *CRREL Report* 80-19:129-150.

Johnson, L.A. 1981. Revegetation and selected terrain disturbances along the trans–Alaska pipeline, 1975–1978. *CRREL Report* 81–12, Hanover.

Johnson, L.A. Rindge, S.D. and Gaskin, D.A. 1981. Chena River Lakes Project revegetation study, Three year study. *CRREL Report* 81–18, Hanover.

Johnson, L.A. and Van Cleve, K. 1976. Revegetation in arctic and subarctic North America: A literature review. *CRREL Report* 76–15.

Kallio, P., Laine, U. and Makinen, Y. 1969. Vascular flora of Inari Lapland. 1. Introduction and Lycopodiaceae–Polypodiaceae. *Report of the Kevo Subarctic Research Station* 5:1–108.

Kalra, Y.P. 1971. Methods used for soil, plant, and water analysis at the soils laboratory of the Manitoba–Saskatchewan region 1967–1970. *Northern Forest Research Centre, Information Report* NOR–X–11, Edmonton.

Karamanski, T.J. 1979. The Canol Project, A poorly planned pipeline. *The Alaska Journal* 9(4):17–21.

Keele, J. 1910. A reconnaissance across the Mackenzie Mountains on the Pelly, Ross and Gravel Rivers, Yukon Territory and Northwest Territories. *Geological Survey of Canada, Publication Number* 1097, Ottawa.

Kerfoot, D.E. 1972. Tundra disturbance studies in the western Canadian Arctic. *ALUR* 1971–72–11, Ottawa.

Kershaw, G.P. 1981. Maps and mapping in the Mackenzie Mountains with particular reference to the CANOL Project. *Association of Canadian Map Librarians, Bulletin* 39

Kevan, P.G 1971. *Vehicle Tracks on the High Arctic Tundra: An 11 Year Case History Around Hazen Camp, Ellesmere Island, N.W.T.* Canada

Kindle, E.D. 1945. Geological reconnaissance alone the Canol Road, from Teslin River to Macmillan Pass, Yukon. *Geological Survey of Canada, Paper* 45–21, Ottawa.

Kupsch, W.O. 1971. The wells and Canol: a visit after 25 years. *Canadian Geographical Journal* 82:134–141.

Kurfurst, P.J., Isaacs, R.M., Hunter, J.A. and Scott, W.J. 1973. Permafrost studies in Norman Wells region, N.W.T. In *Symposium on Geology of the Canadian Arctic. Saskatoon.* J.D. Aitken and D.J. Glass eds. Geological Association of Canada–Canadian Society of Petroleum Geologists, Ottawa.

Lambert, J.D.H. 1972. Botanical changes resulting from seismic and drilling operations, Mackenzie Delta area. *ALUR* 1971–72–12, Ottawa.

Landales, M. and Scotter, G.W. 1973. *Visitor Impact on Meadows Near Lake O'Hara,*

Yoho National Park. Canadian Wildlife Service Report, Edmonton, Alberta.

Lawson, D.E., Brown, J., Everett, K.R., Johnson, A.W., Komarkova, V., Murray, B.M., Murray, D.F. and Webber, P.J. 1978. Tundra disturbances and recovery following the 1949 exploratory drilling, Fish Creek, Northern Alaska. *CRREL Report* 78–28.

Legget, R.F. 1973. Lessons of North known they just have to be used. *Financial Post* May 26, C-9.

Liss, J.R. 1959. The Norman Wells – Canol Project. *Canadian Army Journal* 13:122–126.

Lloyd, T. 1944. Oil in the Mackenzie Valley. *The Geographical Review* 34:275–307.

Lore, J. 1977. *Tundra Disturbance Study: Burwash Uplands, Yukon Territory*. Unpublished MSc. Thesis, Department of Geography, University of Alberta, Edmonton, Alberta.

Mackay, D., Wing Ng, T., Wan Ying Shiu, and Reuber, B. 1979(draft copy only). *The Degradation of Crude Oil in Northern Soils*. Departments of Chemical Engineering and Applied Chemestry, University of Toronto, Toronto.

Mackay, D., Charles, M.E. and Phillips, C.R. 1975. The physical aspects of crude oil spills on northern terrain (final report). *ALUR* 74–75–84, Ottawa.

Mackay, J.R. 1970. Disturbances to the tundra and forest tundra environment of the western Arctic. *Canadian Geotechnical Journal* 7(4):420–432.

MacKenzie, Alexander. 1801. *Voyages From Montreal On The River St. Lawrence Through The Continent of North America to the Frozen and Pacific Oceans in the Years 1789 and 1793*. Reprinted 1971, M.G. Hurtig Ltd., Edmonton.

MacNeish, J.H. 1957. The Poole Field Letters, 1913. *Anthropologica* 4:47–60.

Martell, A.M. and Fuller, W.A. 1979. Comparative demography of *Clethrionomys rutilus* in taiga and tundra in the low Arctic. *Canadian Journal of Zoology*, 57(11):2106–2120.

Martell, A.M. and Pearson, A.M. 1978. The small mammals of the Mackenzie Delta Region, Northwest Territories, Canada. *Arctic*, 31(4):475–488.

McCown, D.D. and Deneke, F.J. 1972. Plant germination and seedling growth as affected by the presence of crude petroleum. In *Proceedings of the Symposium on the Impact of Oil Resource Development on Northern Plant Communities, Occasional Publications on Northern Life, Number* 1, Institute of Arctic Biology, University of Alaska, Fairbanks, 44–51.

McCown, B.H., Deneke, F.J., Rickard, W.E. and Tieszen, L.L. 1972. The response of Alaskan terrestrial plant communities to the presence of petroleum. In *Proceedings of the Symposium on the Impact of Oil Resource Development on Northern Plant*

Communities, Occasional Publications on Northern Life, Number 1, Institute of Arctic Biology, University of Alaska, Fairbanks, 34–43.

McKeague, J.A. 1976. *Manual on Soil Sampling and Methods of Analysis.* Subcommittee of Canada Soil Survey, Committee on Methods of Analysis, Ottawa.

McKendrick, J.D. and Mitchell, Wm.W. 1978. Fertilizer and seeding oil-damaged Arctic tundra to effect vegetation recovery, Prudhoe Bay, Alaska. *Arctic* 31(3):296–304.

Meyers, C.V. ca.1945. *Oil to Alaska, Canol Unveiled.* Douglas Printing Co., Edmonton.

Millen, M. 1974. Before oil gushed at Norman Wells. *North* 21(1):6–9.

Money, A.K. 1943. *Diary Report of Reconnaissance Trip, Canol to MacMillan[sic] Pass.* J.Gordon Turnbull and Sverdrup and Parcel, Architect Engineer, Canol Project, Edmonton.

Montgomery, R.H. 1944. *The Canol Pipe Line[sic] Road.* Library of Surveys and Mapping Branch, Geological Survey of Canada, Ottawa.

Neuberger, R.L. 1948. Great Canol fiasco. *American Mercury* 66(April):415–421.

Odum, E.P. 1971. *Fundamentals of Ecology* (third edition). W.B. Saunders Company, Toronto, 157–159.

Palmer, L.J. and Rouse, C.H. 1945. Study of the Alaska tundra with reference to reindeer and other grazing. *U.S. Fish and Wildlife Service Research Report* 10.

Pegan, R.E. 1968. Growth rates of important reindeer forage lichens on the Seward Peninsula, Alaska. *Arctic* 21: 255–259.

Peterson, K.M. and Billings, W.D. 1978. Geomorphic processes and vegetational change along the Mead River Sand Bluffs in Northern Alaska. *Arctic* 31(1):7–23.

Phillips, R.A.J. 1967. *Canada's North.* Macmillan of Canada, Toronto.

Porsild, A.E. 1944a. *Field Notes On Canol Road Botanical Survey.* National Herbarium, National Museums of Canada, Ottawa.

Porsild, A.E. 1944b. *Field Diary of Canol Road Botanical Survey.* National Herbarium, National Museums of Canada, Ottawa.

Porsild, A.E. 1945. The alpine flora of the east slope of Mackenzie Mountains, Northwest Territories. *National Museum of Canada, Bulletin Number* 101 (*Biological Series Number* 30). Edmond Cloutier Printer, Ottawa.

Porsild, A.E. 1951. Botany of southeastern Yukon adjacent to the Canol Road. *National*

Museum of Canada, Bulletin Number 121 (*Biological Series Number* 41). Queens Printer, Ottawa.

Porsild, A.E. and Cody, W.J. 1980. *Vascular Plants of Continental Northwest Territories, Canada.* National Museums of Canada, Ottawa.

Prest, V.K. 1969. Retreat of Wisconsin and recent ice in North America. *Geological Survey of Canada, Map* 1257A, Ottawa.

Prest, V.K., Grant, D.R. and Rampton, V.N. 1967. Glacial Map of Canada. *Geological Survey of Canada, Map* 1253A, Ottawa.

Pruitt, W.O. 1970. Some ecological aspects of snow. In *Proceedings of the Helsinki Symposium on Ecology of the Subarctic Regions.* UNESCO, Paris.

Pruitt, W.O. Jr. 1978. *Boreal Ecology*. Edward Arnold, London.

Pulliainen, E. 1971. Nutritive values of some lichens used as food by reindeer in northern Lapland. *Zool. Fennici* 8:385-389.

Rand, A.L. 1945a. Mammal investigations on the Canol Road, Yukon and Northwest Territories, 1944. *National Museum of Canada, Bulletin Number* 99 (*Biological Series Number* 28). Edmond Cloutier Printer, Ottawa.

Rand, A.L. 1945b. Mammals of Yukon. *National Museum of Canada, Bulletin Number* 100 (*Biological Series Number* 29). Edmond Cloutier Printer, Ottawa.

Rand, A.L. 1946. List of Yukon birds and those of the Canol Road. *National Museum of Canada, Bulletin Number* 105 (*Biological Series Number* 33). Edmond Cloutier Printer, Ottawa.

Raup, H.M. 1969. Observations on the relation of vegetation to mass-wasting processes in the Mesters Vig District, Northeast Greenland. *Meddelelser om Gronland*, 176(6):180-183.

Richardson, H.W. 1944a. Finishing the Alaska Highway. *Engineering News - Record* 132(Jan.):94-103.

Richardson, H.W. 1944b. Controversial Canol. *Engineering News - Record* 132(May):78-84.

Rickard, W.E.Jr. and Brown, J. 1974. Effects of vehicles on Arctic tundra. *Environmental Conservation* 1(1):55-62.

Riewe, R.R. 1979. Interactions between wildlife, trapper-hunters and seismic lines in the Mackenzie Valley region, N.W.T., Canada. Part 1, Aubry-Colvill Lakes. *North of 60, Environmental Studies Number* 9, *ALUR*, Ottawa.

Savile, D.B.O. 1972. Arctic adaptations in plants. *Canada Department of Agriculture, Monograph No. 6.* Ottawa.

Schledermann, P. 1977. An archaeological survey of Bache Peninsula, Ellesmere Island. *Arctic* 30(4):243–245.

Selous, F.C. 1907. *Recent Hunting Trips In British North America.* Charles Scribner's Sons, New York.

Sheldon, Charles. 1913. *The Wilderness of the Upper Yukon, A Hunter's Explorations for Wild Sheep In Sub-Arctic Mountains.* The Copp Clark Co. Ltd., Toronto.

Simmons, N.W. 1966. *Preliminary Reconnaissance of Mackenzie Mountain Dall Sheep Habitat.* Canadian Wildlife Service Files, Edmonton.

Simmons, N.W. 1967. *Reconnaissance of Mackenzie Mountain Dall Sheep Winter Habitat, March 8-13, 1967.* Canadian Wildlife Service Files, Ottawa.

Simmons, N.W. 1968a. Big Game In the Mackenzie Mountains, N.W.T. *Transactions, Federal-Provincial Wildlife Conference, Ottawa.* Canadian Wildlife Service, Ottawa.

Simmons, N.W. 1968b. *Non-resident Big Game Hunting In Game Management Zone 12, Mackenzie Mountains, N.W.T.* Canadian Wildlife Service Files, Edmonton.

Simmons, N.W. 1969a. *Aerial Dall Sheep and Woodland Caribou Surveys In Game Management Zones 12 and 19, Mackenzie Mountains, N.W.T., March 7-15, 1969.* Canadian Wildlife Service Files, Edmonton.

Simmons, N.W. 1969b. *Aerial Dall Sheep Survey In Game Managemenet Zones 12 and 19, Mackenzie Mountains, April 7-15, 1968.* Canadian Wildlife Service Files, Ottawa.

Simmons, N.W. 1969c. *Non-resident Big Game Hunting In Game Management Zone 12, 1965 through 1968. Canadian Wildlife Service, Progress Note* 11, Ottawa.

Simmons, N.W. 1970a. *Aerial Woodland Caribou Surveys in Game Management Zone 12, Mackenzie Mountains, N.W.T., February-March 1970.* Canadian Wildlife Service Files, Ottawa.

Simmons, N.W. 1970b. *A management plan for big game in the Mackenzie Mountains. Progress Report, N.W.T.* Canadian Wildlife Service Files, Ottawa.

Simmons, N.W. and Cody, W.J. 1974. *A Proposal for Ecological Reserves In The Northwest Territories, Plains of Abraham, Glacier Lake, Brackett Lake, Pilot Lake.* CCIBP/CT Panel 10. Library, Agriculture Canada Herbarium (unplub), Ottawa.

Stager, J.K. 1971. Fur trading posts in the Mackenzie region up to 1850. In *Canada's Changing North.* W.C. Wonders ed. McClelland and Stewart Ltd., Toronto, 50–58.

Steere, W.C. 1978. The Mosses of Arctic Alaska. *Bryophytorum Bibliotheca* 14. J. Cramer, Lehre.

Stefansson, Vilhjalmur. 1941. *Foreign Affairs*. July.

Stefansson, Vilhjalmur. 1942. *Local Oil Supply Yukon, Alaska and Bering Sea*. Yukon Archives, Whitehorse.

Synergy West Ltd. 1975. *Canol Road Clean-Up Assessment Study*. Synergy West Ltd., Calgary.

Thomson, D.W. 1970a. Oil over the mountains. *North* 17(2):14–23.

Thomson, D.W. 1970b. Oil over the mountains. *North* 17(3):38–44.

Thomson, J.W. 1967. *The Lichen Genus Cladonia in North America*. University of Toronto Press, Toronto.

Thomson, J.W. 1979. *Lichens Of The Arctic Slope*. University of Toronto Press, Toronto.

Tranquillini, W. 1979. Physiological Ecology of the Alpine Timberline: Tree Existence In High Altitudes With Special Reference to the European Alps. *Springer Ecological Studies, Volume 31.* Springer Verlag, New York.

Truman Committee. 1944a. *United States Congress, Hearings Before a Special Committee Investigating the National Defence Program, 78 th Congress, 1st. Session, Part 22, The Canol Project.* United States Covernment Printing Office, Washington, 9287–9935.

Truman Committee. 1944b. *United States Congress Additional Report of the Special Committee Investigating the National Defence Program, 78 th Congress 1st. Session, Report No. 10 Part 14, The Canol Project.* United States Government Printing Office, Washington.

United States Army. 1950. *Historical Record CANOL Project*. Alaska Corps of Engineers, Anchorage.

Walker, D.A., Webber, P.J., Everett, K.R. and Brown, J. 1978. Effects of crude and diesel oil spills on plant communities at Prudhoe Bay, Alaska, and the derivation of oil spill sensitivity maps. *Arctic* 31(3):242–259.

Webb, R.H., Ragland, H.C., Godwin, W.H. and Jenkins, D. 1978. Environmental effects of soil property changes with off-road vehicle use. *Environmental Management* 2(3):219–234.

Wein, R.W. 1974. Recovery of vegetation in Arctic regions after burning *Environmental Social Committee, Northern Pipelines, Task Force on Northern Development, Report* 74-6:1–42.

Wein, R.W. and Bliss, L.C. 1973. Experimental crude oil spills on Arctic plant communities. *Journal of Applied Ecology* 10:671–682.

Wein, R.W. and Bliss, L.C. 1973. Changes in *Eriophorum* tussock communities following fire. *Ecology* 54:845–852.

Wein, R.W. and Bliss, L.C. 1974: Primary production in arctic cottongrass tussock tundra communities. *Arctic and Alpine Research* 6:261–274.

Westlake, D.W.S., Jobson, A.M. and Cook, F.D. 1978. *In situ* degradation of oil in a soil of the boreal region of the Northwest Territories. *Canadian Journal of Microbiology* 24(3):254–260.

Westlake, D.W.S. and Cook, F.D. 1980. Petroleum biodegradation potential of northern Puget Sound and Strait of Juan De Fuca environments. *Interagency Energy/Environment R & D Program Report.* United States Environmental Protection Agency, Washington.

Wiken, E.B. 1979. Rationale and methods of ecological land surveys: An overview of Canadian approaches. In *Land/Wildlife Integration. Ecological Land Classification Series No. 11.* D.G. Taylor ed. Land Directorate, Environment Canada, Ottawa, 11–21.

Willard, B.E. and Marr, J.W. 1970. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. *Biological Conservation* 3(3):181–190.

Wolf, J.O. and Cowling, J. 1981. Moose browse utilization in Mount McKinley National Park, Alaska. *Canadian Field-Naturalist* 95(1):85–88.

Wolf, J.O. and Zasada, J.C. 1979. Moose habitat and forest succession on the Tanana River floodplain and Yukon–Tanana upland. *Proceedings of the 15th North American Moose Conference and Workshop.* pp.213–244.

Woo, V. and Zoltai, S.C. 1977. Reconnaissance of the soil and vegetation of Somerset and Prince of Wales Islands, N.W.T. *Information Report* NOR–X–186, Northern Forest Research Centre, Edmonton.

Woodman, L.L. 1977. Canol: pipeline of brief glory. *The Northern Engineer* 9(2):14–28.

Youngman, P.M. 1975. Mammals of the Yukon Territory. *Publications in Zoology, Number* 10. National Museums of Canada, Ottawa.

Younkin, W.E. 1976. Revegetation studies in the Northern Mackenzie Valley Region. *Biological Report Series, Volume* 38, Canadian Arctic Gas Study Ltd., Calgary.

Yurtsev, B.A. and Korabkov, A.A. 1979. An annotated list of plants inhabiting sites of natural and anthropogenic disturbances of tundra cover: southernmost Chukchi Peninsula. In The biological effect of disturbance plant communities in tundra regions of the Soviet Union. *Biological Papers, University of Alaska* 20:1–18.

Zoltai, S.C. and Woo, V. 1978. Sensitive soils of permafrost terrain. In *Forest Soils and Land Use, Proceedings of the Fifth North American Forest Soils Conference*. pp. 410–424. Colorado State University, Fort Collins.

APPENDIX I: SOURCES OF HISTORICAL INFORMATION

Published Material

Many articles pertaining to the CANOL Project have been published since 1943 (e.g. see Finnie in Selected References). These are found in newspapers, popular magazines, trade journals and scientific journals as well as in privately printed books. Most primary sources deal with the Project and its facilities and not with the environment which was affected. Secondary sources tend to have a similar approach but are more general in nature and fail to be specific.

Unpublished Material Most of the unpublished material is the property of Imperial Oil Limited, Bechtel Corporation or individuals originally involved with the project. R.S.Finnie of California has retained many interesting documents pertaining to the CANOL Project, including a diary of his two-year involvement with the Project and a copy of the log of G.H.Blanchet's survey of the route by dog team in October-December 1942.

More recent information on the CANOL Project took the form of consultants' reports to industry but only two such cases were found (R.M.Hardy and Associates 1971 and 1972).

Archival Material

This type of material was gathered from the following major depositories:

1. Public Archives of Canada, Ottawa;
2. Yukon Territorial Archives, Whitehorse;
3. Office of the Chief of Military History, Washington, D.C.

The Public Archives of Canada has material concerning diplomatic discussions associated with the CANOL Project, reports of the Joint Defense Board and copies of many memoranda of the Northwest Service Command, United States Army. The Yukon Archives has microfilm of Northwest Service Command documents, communiques to the United States Army from the civilian contractors and information packages prepared for the 'Truman Hearings' of 1943-44. Due to logistical and financial constraints, the Northwest Territories Archives could not be visited but is known to contain pertinent documents.

Interviews

People who were directly involved with the CANOL Project also provided information. Interviews have been held with individuals associated with the planning, surveying, construction and/or salvage phases of the Project. Such sources are difficult to discover and may not always be reliable. Many people involved with the CANOL Project were impossible to locate or are deceased.

R.S.Finnie has proved to be a valuable source, providing detailed information on CANOL from his unique perspective of the Project. Through his involvement from May 1942 to the spring of 1944, he covered all phases of CANOL as an historian/documentor. During this period he held the office of 'Northern Liason Officer' and was also 'Project Historian' for the U.S.Army. Supplemented by his detailed diary, he has clarified many questions that would have otherwise remained unanswered.

Photographic Material

Both aerial and terrestrial photographs were consulted during this study. Aerial photography was obtained through the National Air Photo Library, Ottawa and the Defense Intelligence Agency, Washington, D.C. Terrestrial photography was aquired from private collections and from the Photographic Division of the National Museums of Canada and the National Photographic Collection, Ottawa.

Aerial photography is available from six missions flown between 1943 and 1974. Only the 1944 (1:24,760 scale), 1949-51 (1:31,200 scale) and 1974 (1:12,000 and 1:40,000 scale) series cover the entire study area. The 1943 (1:41,670 scale), 1963 (1:15,600 scale) and 1972 (1:24,000 scale) flights each include only portions of the study area.

Terrestrial photographs taken prior to 1945 came primarily from three sources. The National Photographic Collection contains some photographs taken during thhe construction of the Project. The National Museums of Canada Photographic Collection contains numerous photographs taken by A.E.Porsild during September 1944. Private collections include those of A.Hemstock (formerly with Imperial Oil) and R.S.Finnie (retired from Bechtel Corporation). Mr. Finnie's collection numbers in the thousands and is complete with captions and locations.

APPENDIX II: SOILS AND DISTURBANCE SUBSTRATES - RAW DATA

Appendix II
Soils and Disturbance Substrates: Raw Data

Site	Seq	Type	Veg	Asp	Slope Ac	Slope Al	Drain	Moist	Horiz	SurfD	SubD	SurfpH	SubpH	SurfO	SurfMoist	SubMoist	Temp	Root	G	Surface Layer Texture 10	40	200	Pan	Total
002	0	0	1	000	020	025	2	3	4	100	040	43	46	364	0833	0697	471	0400	00	0052	0086	0129	0105	00372
002	0	1	1	000	000	030	2	3	1	280		46		046	0116		591	0200	80	1868	1067	0716	0607	04258
002	0	5	1	000	000	030	2	3	5	020	050	47	43	689	0944	0605	530	0330	00	0008	0050	0094	0050	00202
002	0	6	1	000	010	020	2	3	1	330		57		000	0042		635	0250	90	2259	2799	0614	0230	05902
003	0	0	1	270	005	015	2	3	5	050	070	47	53	1000	3002	0689	500	0470	00	0000	0000	0000	0000	00000
003	0	1	1	080	020	010	2	3	1	280		46		046	0116		591	0200	80	1868	1067	0716	0607	04258
003	0	3	1	090	020	040	2	2	1	370		48		020	0044		561	0320	95	4728	1942	0552	0174	07396
003	0	8	1	000	000	020	2	3	3	005	005	36	42	911	0430	0181	533	0000	20	0264	0226	0841	1090	02421
009	0	0	1	225	005	000	3	3	2	180	420	43	48	120	0360	0250	550	0430	15	0282	0308	0170	0037	00797
009	0	1	1	180	025	020	2	2	1	160		59		057	0083		545	0160	80	1716	1114	0556	0328	03714
009	0	3	1	196	020	020	2	3	2	050		38	51	114	0264		610	0290	00	0214	0347	1386	0253	02200
009	0	5	1	135	035	015	2	3	3	050	140	44	48	109	0271	0191	490	0160	00	0010	0108	0325	0428	00871
009	0	6	1	000	010	000	1	2	1	210		76		000	0054		662	0000	95	2299	1191	0521	0381	04392
009	0	7	1	090	025	015	2	3	1	170		76		055	0090		570	0170	90	1109	0828	0382	0219	02538
011	0	0	3	045	010	015	3	5	4	205	015	69	64	1000	4752	1249	515	0370	00	0000	0000	0000	0000	00000
011	0	1	3	050	005	010	3	3	1	160		71		078	0207		584	0160	85	0858	0463	0380	0259	01960
014	0	0	3	090	000	000	3	4	2	170	450	42	52	351	1084	0160	485	0500	03	0012	0195	1523	0396	02126
014	0	1	3	180	035	025	2	3	1	220		66		000	0194		577	0200	90	0878	0515	0346	0183	01922
014	0	6	3	255	010	070	3	4	1	320		60		000	0160		541	0150	30	0410	0930	1222	0510	03072
016	0	0	3	000	015	030	3	5	1	490		40		1000	2724		464	0090	00	0000	0000	0000	0000	00000
016	0	3	3	000	040	040	3	5	3	060	170	44	43	1000	5411	3906	444	0240	00	0000	0000	0000	0000	00000
016	0	5	3	000	000	000	3	5	2	110	230	40	47	1000	2610	6389	423	0220	00	0000	0000	0000	0000	00000
020	0	0	2	225	000	000	3	3	3	060	160	43	50	163	0491	0719	499	0490	25	0220	0294	0428	0193	01135
020	0	1	2	064	010	010	2	3	1	210		79		153	0137		519	0180	85	0685	1010	0556	0388	02639
020	0	5	2	058	030	010	3	3	3	110	110	48	55	150	0630	0214	519	0480	20	0258	0341	0535	0592	01726
020	0	6	2	000	010	000	2	3	1	100		75		000	0124		540	0000	95	0943	0700	0593	0974	03210
020	0	7	2	225	025	005	2	3	2	160	150	78	72	000	0169	0140	537	0130	55	0801	1563	0924	0631	03919
031	0	0	1	270	005	015	2	3	5	050	070	47	53	1000	3002	0689	500	0470	00	0000	0000	0000	0000	00000
031	0	4	1	100	000	000	2	3	4	110	040	46	43	085	0158	0146	546	0150	50	1654	1206	0982	0851	04693
031	0	5	1	065	020	010	2	3	7	020	060	42	47	504	1195	0891	509	0320	00	0043	0081	0149	0100	00373
031	2	3	1	286	005	005	2	3	2	130	330	46	51	028	0007	0059	525	0130	60	1662	0939	0514	0257	03691
031	2	6	1	043	025	015	2	3	2	190	260	52	50	025	0101	0058	545	0150	05	0725	1117	2069	0206	04117
031	2	8	1	045	020	005	2	3	5	050	190	44	50	594	0934	0605	505	0490	00	0108	0303	0695	0172	01278
035	0	0	2	360	020	030	2	3	3	050	120	70	72	068	0238	0668	525	0330	00	0002	0012	0443	1502	01959
035	0	1	2	000	015	015	2	3	1	180		79		000	0087		600	0180	85	1100	0575	0510	0530	02715
035	0	3	2	360	000	085	2	3	1	230		70		157	0280		540	0150	70	0575	0194	0493	0629	01891
035	0	6	2	360	005	030	2	2	1	190		77		000	0084		545	0120	90	1359	1094	0279	0325	03057
037	0	0	1	082	020	010	4	3	2	070	0230	78	73	000	0261	0272	555	0300	00	0029	0093	1320	1099	02541
037	0	1	1	278	000	000	3	3	2	190	060	78	73	000	0066	0106	610	0180	60	3790	1922	0607	0318	06637
037	0	3	1	225	045	000	4	4	1	330		78		000	0202		595	0330	70	0530	0562	1128	0867	03087
037	0	6	1	000	015	025	4	5	2	180	150	71	79	139	0351	0238	578	0200	00	0005	0059	0986	1753	02803
037	0	7	1	340	070	020	3	3	2	040	190	68	76	106	0265	0113	567	0200	10	0210	0220	0444	0474	01348

continued

Appendix II continued

Site	Seq	Type	Veg	Asp	Slope Ac	Slope Al	Drain	Moist	Horiz	SurfD	SubD	SurfpH	SubpH	SurfO	SurfMoist	SubMoist	Temp	Root	G	Surface Layer Texture 10	40	200	Pan	Total
072	0	0	5	093	005	000	2	4	3	050	090	41	41	1000	3098	3098	401	0110	00	0000	0000	0000	0000	00000
072	0	1	5	222	000	010	1	3	1	180		55		011	0087		489	0180	90	1053	0227	0654	0436	02370
072	0	3	5	172	010	020	2	4	1	170		50		000	0106		455	0170	85	0975	0267	1066	0763	03071
072	0	5	5	132	270	000	2	4	1	170		50		000	0106		455	0170	85	0975	0267	1066	0763	03071
072	0	6	5	056	010	040	4	4	1	240		64		000	0083		480	0030	85	1674	0289	1364	0748	04075
074	0	0	2	064	025	015	2	5	2	090	220	73	76	196	0699	0236	576	0340	60	0132	0106	0460	0580	01278
074	0	6	2	071	050	035	3	6	1	120		81		000	0084		590	0080	85	1563	0288	0558	1324	03733
074	1	1	2	070	045	020	3	5	1	250		80		000	0278		620	0230	75	0528	0520	0680	1381	03109
074	2	1	2	070	050	040	3	7	3	200	180	69	64	110	0553	2964	514	0460	25	0945	0331	0514	0903	02693
075	0	0	7	297	010	050	1	1	0	000		54		001	0000		720	0000	00	0000	0000	0000	0000	00000
075	0	1	7	278	025	070	1	3	1	220		69		000	0100		528	0170	95	2552	0391	1231	0652	84802
076	0	0	5	320	015	000	2	4	2	020	270	52	51	106	0493	0104	524	0110	40	0110	0189	0853	0160	01312
076	0	1	5	125	040	020	2	3	1	260		63		000	0119		626	0280	85	1903	0503	1192	0691	04289
076	0	2	5	053	010	011	2	5	1	340		54		000	0071		558	0230	95	0761	0151	0109	0048	01069
076	0	6	5	350	020	055	2	4	1	240		54		000	0109		589	0180	70	0452	0157	1464	1369	03442
078	0	0	5	197	030	000	2	4	3	020	040	43	50	352	1562	0286	427	0250	03	0020	0010	0005	0005	00040
078	0	1	5	096	030	020	2	3	2	140	120	54	49	020	0152	0177	567	0260	90	0453	0196	0796	0558	02003
078	0	6	5	338	030	020	2	4	1	230		50		022	0109		490	0160	85	0314	0114	0833	0965	02226
078	0	7	5	186	040	010	2	4	3	120	060	58	58	000	0132	0132	550	0070	90	1561	0483	1402	0574	04020
082	0	0	2	251	090	070	2	4	2	060	270	82	80	000	0349	0575	530	0330	20	0054	0099	0999	0860	02012
082	0	1	2	216	040	000	2	3	2	220	090	81	71	000	0069	0292	540	0300	85	1036	0588	0950	0740	03314
082	0	6	2	259	080	005	2	3	1	260		71		000	0084		557	0260	90	1151	0747	1277	0833	04008
083	0	0	6	210	030	010	3	3	3	125	040	76	79	074	0274	0080	510	0165	25	1068	1037	0849	1207	04161
083	0	6	6	126	000	040	2	3	1	370		75		000	0104		496	0120	85	2270	0621	0668	1089	04648
083	0	7	6	273	075	075	3	5	1	240		80		000	0227		485	0150	75	2327	0655	0403	2331	05716
084	0	0	3	096	030	020	3	7	2	050	350	82	81	085	0184	0276	490	0350	00	0395	0187	0386	2383	03351
084	0	1	3	195	010	025	2	3	4	145	025	76	76	000	0090	0090	615	0175	75	2283	0796	0837	1143	05059
084	0	6	3	129	050	030	3	6	1	330		83		062	0555		560	0330	40	0345	0119	0182	1688	02334
087	0	0	6	323	010	000	3	4	1	450		81		000	0163		506	0380	01	0524	0769	2901	1946	06140
087	0	1	6	005	000	020	2	3	1	260		73		000	0138		513	0130	35	1554	0628	1677	1421	05280
088	0	0	6	323	010	000	3	4	1	450		81		000	0163		506	0380	01	0524	0769	2901	1946	06140
088	0	1	6	282	020	010	2	3	1	320		74		000	0112		553	0200	85	1412	0561	1415	1077	04465
088	0	3	6	354	050	020	2	3	2	125	035	75	77	000	0139	0146	509	0130	85	0315	0127	0185	0503	01130
088	0	6	6	341	000	005	1	6	1	180		72		000	0048		525	0000	99	0885	0258	0024	0084	01251
089	0	0	6	323	010	000	3	3	2	220	150	78	72	000	0140	0250	497	0240	15	0383	0495	3339	3136	07353
089	0	1	6	242	020	010	2	3	1	330		82		000	0138		494	0000	85	1358	0465	2146	1251	05220
089	0	6	6	228	070	020	2	3	0	000				000	0000			0000	00	0000	0000	0000	0000	00000
091	0	0	6	210	030	010	3	3	3	125	040	76	79	074	0274	0080	510	0165	25	1068	1037	0849	1207	04161
091	0	1	6	059	000	010	2	3	4	145	025	76	76	000	0090	0090	615	0175	75	2283	0796	0837	1143	05059
091	0	3	6	154	050	050	2	3	1	380		82		000	0089		470	0380	85	2294	0253	0142	0679	03368
093	0	0	2	255	150	020	2	2	4	100	120	72	77	262	0963	0328	575	0450	10	0007	0095	0339	0692	01133
093	0	1	2	169	085	015	2	3	1	310		83		000	0119		627	0310	90	0626	0327	1042	0446	02441
093	0	2	2	151	080	020	2	3	1	200		79		000	0120		564	0150	80	0781	0448	0992	0786	03007
093	0	6	2	233	140	005	3	5	1	300		81		000	0156		530	0060	80	0633	0496	1048	0807	02984

continued

Appendix II continued

Site	Seq	Type	Veg	Asp	Slope Ac	Slope Al	Drain	Moist	Horiz	SurfD	SubD	SurfpH	SubpH	SurfO	SurfMoist	SubMoist	Temp	Root	Surface Layer Texture G	10	40	200	Pan	Total
094	0	0	2	148	030	000	3	5	3	070	110	68	70	542	2274	0948	505	0360	00	0018	0118	0084	0193	00413
094	0	1	2	159	040	010	2	3	1	280		77		000	0105		544	0280	90	1493	1097	0871	1293	04754
094	0	3	2	177	015	015	2	4	2	100	120	82	83	000	0241	0113	537	0190	25	0869	0563	0867	0813	03112
094	0	5	2	180	010	010	2	4	2	100	120	82	83	000	0241	0113	537	0180	25	0869	0563	0867	0813	03112
096	0	0	2	097	040	000	2	4	2	060	360	67	74	218	0733	0251	566	0410	50	0155	0170	0312	0377	01014
096	0	1	2	257	040	020	2	3	1	260		78		000	0161		561	0260	90	0967	1208	1034	1346	04555
096	0	3	2	224	035	020	2	3	1	250		75		000	0230		565	0160	85	0518	0465	1449	1392	03824
096	0	6	2	016	020	020	2	2	1	280		76		000	0136		483	0280	95	0934	0380	0431	0591	02336
098	0	0	7	279	010	070	2	4	1	560		71		001	0216		534	0260	03	0239	0260	2184	1896	04579
098	0	1	7	217	040	000	1	2	1	350		81		000	0112		520	0250	95	3567	0778	1437	1596	07378
098	0	6	7	222	020	040	1	2	1	380		77		000	0097		519	0000	90	1445	0856	0878	1108	04287
101	0	0	2	232	070	040	2	3	3	030	200	75	75	1000	0875	0708	536	0325	00	0000	0000	0000	0000	00000
101	0	1	2	224	015	010	2	2	1	270		78		070	0043		604	0270	90	2163	1209	1696	1093	06161
101	0	3	2	181	020	000	2	3	1	290		73		000	0217		588	0250	85	0177	1254	1263	0867	03561
101	0	5	2	214	030	040	2	2	1	330		75		101	0081		647	0330	75	2079	0636	1095	0845	04655
101	0	6	2	312	030	070	2	3	1	210		80		000	0595		621	0210	80	2690	1682	1372	0881	06625
101	0	7	2	145	060	090	2	3	1	250		76		094	0133		620	0250	75	1088	0715	0553	1903	04259
101	1	8	2	177	010	010	3	5	2	200	110	74	76	526	1190	0100	550	0310	00	0082	0254	0390	0474	01200
101	2	8	2	186	000	005	2	3	3	020	050	68	72	1000	0182	1297	560	0290	00	0000	0000	0000	0000	00000
101	3	8	2	183	035	045	2	3	2	110	150	70	76	556	0706	0455	608	0220	30	0106	0140	0452	0995	01693
103	0	0	7	132	210	010	1	1	0	000		00		001	0000		670	0000	00	0000	0000	0000	0000	00000
103	0	1	7	052	000	015	2	3	1	190		77		000	0087		595	0130	85	1403	0644	1499	0680	04226
103	0	6	7	071	040	110	2	3	1	200		48		015	0101		506	0150	98	1861	0524	1148	0512	04045
104	0	0	4	242	040	040	2	3	4	050	280	42	42	1000	2698	0037	450	0380	00	0000	0000	0000	0000	00000
104	0	1	4	065	050	035	2	3	1	320		55		017	0129		600	0320	95	1494	0628	2121	0711	04954
104	0	3	4	264	000	040	2	3	1	370		43		017	0097		562	0230	55	0499	0469	2357	0908	04233
104	0	6	4	133	020	030	2	3	1	310		55		015	0103		574	0160	85	1880	1087	2004	0642	05614
104	0	8	4	104	150	020	2	3	2	100	180	44	45	000	0202	0139	569	0000	10	0338	0466	3644	1643	06091
105	0	0	3	097	040	020	3	7	2	100	160	44	42	317	3119	0550	490	0260	00	0045	0141	0358	0268	00812
105	1	8	3	055	030	050	2	7	3	130	100	38	45	1000	0429	0291	494	0000	00	0000	0000	0000	0000	00000
105	2	8	3	164	020	050	3	7	3	080	320	38	42	1000	0402	0140	487	0000	00	0000	0000	0000	0000	00000
107	0	0	5	183	030	060	2	3	5	020	050	40	45	1000	1808	0748	492	0380	00	0000	0000	0000	0000	00000
107	0	3	5	259	005	005	2	3	1	300		56		000	0107		593	0170	65	2382	1740	2403	0216	06791
107	0	5	5	032	010	040	2	3	4	010	040	42	43	1000	0667	0631	469	0220	00	0000	0000	0000	0000	00000
107	0	6	5	041	020	030	2	3	1	250		44		000	0056		652	0050	75	2988	1275	0444	0137	04844
107	0	7	5	157	030	010	2	3	1	190		43		000	0116		582	0190	60	1408	0855	0490	0523	03276
110	0	0	1	241	065	040	2	4	3	120	010	60	59	1000	3535	0510	472	0320	00	0000	0000	0000	0000	00000
110	0	2	1	215	030	030	2	4	1	450		57		052	0133		555	0450	40	2177	1328	0817	1245	05567
110	0	6	1	306	085	040	2	3	2	220	150	66	71	061	0115	0094	608	0240	40	1870	1863	0995	0529	05257
112	0	0	2	007	040	010	1	2	3	010	050	74	75	1000	1782	0838	591	0350	00	0000	0000	0000	0000	00000
112	0	1	2	139	005	005	2	3	1	250		80		081	0066		720	0180	90	2208	1266	1811	1121	06406
112	0	3	2	143	035	015	2	3	1	280		77		128	0105		668	0280	85	0793	0455	0770	0578	02596
112	0	6	2	175	020	000	3	4	2	150	070	74	77	000	0287	0288	536	0220	00	0000	0004	0878	2845	03727
112	0	7	2	035	010	010	2	3	1	290		79		081	0072		654	0270	85	1942	0440	0651	2087	05120
112	1	8	2	341	005	020	4	4	2	220	130	74	76	338	0601	0348	556	0350	00	0127	0300	0550	1546	02523
112	2	8	2	345	010	000	2	3	2	020	270	75	75	1000	0000	0268	618	0000	00	0000	0000	0000	0000	00000

Site - site number (e.g. 001 to 118)
Seq - 0=only disturbance of that type sampled at that site
1=1st, 2=2nd and 3=3rd of two or more disturbances of that type sampled at that site.
Type - Site type
(1) Road
(2) False Start Road
(3) Bladed Trail
(4) Camp Yard
(5) Bulldozer Track
(6) Gravel Pit
(7) Gravel Pit Access Road
(8) Oil Spill
Veg - Physiognomic plant community
(1) Erect Deciduous Shrub Tundra
(2) Decumbent Shrub Tundra
(3) Sedge Meadow Tundra
(4) Lichen Heath Tundra
(5) Fruticose Lichen Tundra
(6) Cushion Plant Tundra
(7) Crustose Lichen Tundra
(8) Forb Meadow Tundra
Asp - Aspect in degrees
Slope - Slope in degrees
Al=Along (e.g. 020=2.0)
Ac=Across (e.g. 025=2.5)
Drain - Interior soil drainage
(1) excessive
(2) free
(3) impeded
(4) seasonally wet
Moist - Soil Moisture
(1) Xeric
(2) Subxeric
(3) Submesic
(4) Mesic
(5) Subhygric
(6) Hygric
(7) Hydric
(8) Aquatic
Hor - # of horizons
SurfD - Surface layer depth (e.g. 105=10.5 cm)
SubD - Subsurface layer depth (e.g. 100=10.0 cm)
SurfpH - Surface layer pH (e.g. 43=4.3)
SubpH - Subsurface layer pH (e.g. 46=4.6)
SurfO - Organic content of surface layer (e.g. 364=36.4%)
SurfMoist - Moisture content of surface layer (e.g. 0833=83.3%)
SubMoist - Moisture content of subsurface layer (e.g. 0697=69.7%)
Temp - Temperature at 10 cm depth (e.g. 471=47.1 degree F.)
Root - Maximum rooting depth (e.g. 0400=40.0 cm)
Surface Texture
G - estimate of total gravel content (e.g. 80=80%)
10 - weight of gravel inadvertently retained in the sample (e.g. 0052=5.2 grams)
40 - weight of coarse sand in sample (e.g.0086=8.6 grams)
200 - weight of medium to fine sand in sample (e.g. 0129=12.9 grams)
Pan - weight of very fine sand, silt and clay in sample (e.g. 0105=10.5 grams)
Total - total weight of sample (e.g. 00372=37.2 grams)
(Any difference between the 'total weight' and the sum of the 4 weights was assumed to be in the pan.)

APPENDIX III: CONTROL-CORRECTED SUBSTRATE CHARACTERISTICS IN THE STUDY AREA PLANT COMMUNITIES

(Fruticose Lichen Tundra not included since only one site sampled)

Appendix III

Table A: Control-corrected substrate characteristics (mean differences) of CANOL disturbances, N.W.T. in Erect Deciduous Shrub Tubdra

Substrate Characteristics	Control		Road over		False Start Road over	Bladed Trail in		Camp Yard over	Bulldozer Track over	Gravel Pit in		Gravel Pit Access Road over		Oil Spill on
	SB	HG	SB	HG	SB	SB	HG	SB	SB	SB	HG	SB	HG	SB
pH	4.8	7.8	+0.4	+0.0	-0.3	-0.2	+0.0	-0.1	+0.0	+1.0	-0.7	+1.2	-1.0	-0.7
Organic Content (%)	70	11	-33	-11	-95	-65	-11	-92	-61	-60	+3	-6	0	-25
b Moisture Content (%)	215	26	-102	-19	-340	-202	-6	-284	-60	-185	+9	-27	+0	-232
Gravel Content (%)	3	0	+71	+60	+40	+47	+70	+50	-5	+54	+0	+75	+10	+10
Coarse to Fine Sand Content (%)	80	56	+26	+33	+63	+53	+10	+72	+11	+48	-19	-8	+2	+67
Very Fine Sand, Silt, Clay Content (%)	20	44	-1	-33	+37	+8	-10	+28	+22	+2	+19	+8	-2	+33
Temperature at -10 cm (°C)	9.4	13.1	+3.6	+3.0	+4.6	+2.7	+2.2	+2.6	+1.5	+6.3	+1.2	+1.1	+0.6	+1.1
Maximum Rooting Depth (cm)	42	30	-22	-12	+13	-21	+3	-32	-16	-24	-10	-26	-10	-22
n	5	1	4	1	1	3	1	1	3	4	1	1	1	2

SB: 'Sombric Brunisol' HG: 'Humic Gleysol'

Appendix III

Table B: Control-corrected substrate characteristics (mean differences) of CANOL disturbances, N.W.T. in Decumbent Shrub Tundra

Substrate Characteristics	Control Humic Regosol	Road over	False Start Road over	Bladed Trail in	Bulldozer Track on	Gravel Pit in	Gravel Pit Access Road over	Oil Spill on
pH	6.9	+0.9	+0.7	+0.5	+0.6	+0.7	+1.4	-0.2
Organic Content (%)	38	-32	-26	-51	-48	-36	-66	-32
Moisture Content (%)	93	-75	-84	-97	-90	-57	-92	-70
Gravel Content (%)	18	+58	+70	+60	+32	+56	+63	+6
Coarse to Fine Sand Content (%)	47	+25	+26	+37	+20	+21	+25	+26
Very Fine Sand Silt Clay Content (%)	53	-5	-26	+3	+13	+4	+42	+34
Temperature at -10 cm (°C)	12.5	+2.1	-0.6	+2.0	+3.0	+0.0	+3.5	+1.1
Maximum Rooting Depth (cm)	38	-11	-30	-15	-6	-22	-17	-10
n	9	10	1	5	3	8	3	5

Appendix III

Table C: Control-corrected substrate characteristics (mean differences) of CANOL disturbances, N.W.T. in Sedge Meadow Tundra

Substrate Characteristics	Control		Road over		Bladed Trail in	Bulldozer Track on	Gravel Pit in		Oil Spill on
	HG	OC	HG	OC	HG	HG	HG	OC	HG
pH	4.2	7.6	+2.4	-0.2	+0.4	+0.0	+1.8	+0.1	-0.6
Organic Content (%)	56	54	-35	-50	+0	+0	-35	-2	+68
Moisture Content (%)	230	247	-89	-232	+269	-11	-92	+37	-270
Gravel Content (%)	1	0	+87	+80	+0	+0	+27	+40	+0
Coarse to Fine Sand Content (%)	73	19	+1	+20	+0	+0	-4	-4	-65
Very Fine Sand, Silt, Clay Content (%)	27	81	-1	-8	+0	+0	+4	+4	-35
Temperature at -10 cm (°C)	8.9	10.1	+5.1	+5.4	-1.1	-2.3	+3.1	+3.9	+0.3
Maximum Rooting Depth (cm)	28	36	-30	-19	+15	+13	-35	-2	-26
n	3	2	1	2	1	1	1	1	2

HG: 'Humic Gleysol' OC: 'Organic Cryosol'

Appendix III

Table D: Control-corrected substrate characteristics (mean differences) of CANOL disturbances, N.W.T. in Lichen Heath Tundra

Substrate Characteristics	Control Dystric Brunosol	Road over	Bladed Trail in	Gravel Pit in	Oil Spill on
pH	4.2	+1.3	+0.1	+1.3	+0.2
Organic Content (%)	100	-98	-98	-98	-100
Moisture Content (%)	270	-257	-260	-260	-250
Gravel Content (%)	0	+95	+55	+85	+10
Coarse to Fine Sand Content (%)	0	+79	+76	+83	+71
very Fine Sand, Silt, Clay Content (%)	0	+21	+24	+17	+29
Temperature at -10 cm (°C)	7.2	+8.4	+6.3	+6.9	+6.7
Maximum Rooting Depth (cm)	38	-6	-15	-22	-38
n	1	1	1	1	1

Appendix III

Table E: Control-corrected substrate characteristics (mean differences) of CANOL disturbances, N.W.T. in Fruticose Lichen Tundra

Substrate Characteristics	Control		Road over		False Start Road over	Bladed Trail in		Bulldozer Track on		Gravel Pit in		Gravel Pit Access Road over
	DB	HR	DB	HR	HR	DB	HR	DB	HR	DB	HR	DB
pH	4.2	4.6	+1.1	+1.2	+0.2	+1.6	+0.9	+0.2	+0.9	+0.6	+1.2	+0.9
Organic Content (%)	68	55	-33	-55	-11	-100	-100	+0	-100	-66	-55	-68
Moisture Content (%)	168	180	-141	-169	-42	-170	-299	-114	-299	-160	-170	-156
Gravel Content (%)	2	20	+87	+68	+55	+65	+85	+0	+185	+78	+58	+74
Coarse to Fine Sand Content (%)	75	87	-11	+26	-2	+94	+64	0	64	34	18	37
Very Fine Sand, Silt, Clay (%)	25	13	11	24	2	5	36	0	36	16	32	13
Temperature at -10 cm (°C)	7.8	7.9	+0.8	+5.3	+1.9	+5.6	+3.0	-1.3	+3.0	+6.2	+4.0	+5.9
Maximum Rooting Depth (cm)	32	11	+1	+12	+12	-21	+6	-16	+6	-21	-1	-18
n	2	2	1	2	1	1	1	1	1	2	2	2

DB: 'Dystric Brunisol' HR: 'Humic Regosol'

Appendix III

Table F: Control-corrected substrate characteristics (mean differences) of CANOL disturbances, N.W.T. in Cushion Plant Tundra

Substrate Characteristics	Control Regosol	Road over	Bladed Trail in	Gravel Pit in	Gravel Pit Access Road over
pH	7.8	-0.3	+0.0	-0.5	+0.4
Organic Content (%)	3	-2	-4	-2	-7
Moisture Content (%)	20	-7	-10	-14	-5
Gravel Content (%)	13	+60	+72	+81	+50
Coarse to Fine Sand Content (%)	62	+2	-26	-17	-30
Very Fine Sand, Silt, Clay Content (%)	38	-2	+26	-17	+30
Temperature at -10 cm (°C)	10.3	+2.2	+1.0	+0.1	-1.4
Maximum Rooting Depth (cm)	27	-16	-2	-22	-2
n	5	4	2	3	1

Appendix III

Table G: Control-corrected substrate characteristics (mean differences) of CANOL disturbances, N.W.T. in Crustose Lichen Tundra

Substrate Characteristics	Control Rockland		Road over		Bladed Trail in	Gravel Pit in	
	Acidic	Basic	Acidic	Basic	Acidic	Acidic	Basic
pH	5.1	7.1	+2.5	+1.0	+0.3	-0.3	+0.6
Organic Content (%)	1	1	-1	-1	+0	+0	-1
Moisture Content (%)	0	22	+9	-11	+0	+10	-12
Gravel Content (%)	100	3	-10	+92	+0	-2	+87
Coarse to Fine Sand Content (%)	0	56	+74	+2	+0	+77	+5
Very Fine Sand, Silt, Clay Content (%)	0	44	+26	-2	+0	+23	-5
Temperature at -10 cm (°C)	20.8	11.9	-7.4	-0.9	-7.9	-10.5	-0.9
Maximum Rooting Depth (cm)	0	26	+15	-1	+0	+15	-26
n	2	1	2	1	1	1	1

APPENDIX IV: FLORA

SYSTEMATIC LIST OF MAJOR PLANT TAXA

OCCURRING IN THE STUDY AREA

NON-VASCULAR PLANTS: LICHENS

ACAROSPORACEAE
Acarospora schleicheri (Ach.)Mass.
Sporastatia testudinea (Ach.)Mass.

BAEOMYCETACEAE
Baeomyces carneus (Retz.)Florke
Baeomyces roseus Pers.
Baeomyces rufus (Huds.)Rebent.

BUELLIACEAE
Buellia disciformis (Fr.)Mudd
Buellia immersa Lynge
Buellia papillata (Sommerf.)Tuck.
Buellia scabrosa (Ach.)Korb.
Rinodina roscida (Somm.)Arn.
Rinodina turfacea (Wahlenb.)Korb.

CLADONIACEAE
Cladonia sp.
Cladonia acuminata (Ach.)Norrl.
Cladonia amaurocraea (Floerke)Schaer.
Cladonia arbuscula (Wallr.)Rabenh.
Cladonia bacillaris (Ach.)Nyl.
Cladonia bacillariformis (Nyl.)Vain.
Cladonia bellidiflora (Ach.)Schaer.
Cladonia botrytes (Hag.)Willd.
Cladonia cariosa (Ach.)Spreng.
Cladonia carneola Fr.
Cladonia cenotea (Ach.)Schaer.
Cladonia chlorophaea (Floerke)Spreng.
Cladonia coccifera (L.)Willd.
Cladonia cornuta (L.)Hoffm.
Cladonia crispata (Ach.)Flot.
Cladonia decorticata (Floerke)Spreng.
Cladonia deformis (L.)Hoffm.
Cladonia ecmocyna (Ach.)Nyl.
Cladonia fimbriata (L.)Fr.
Cladonia furcata (Huds.)Schrad.
Cladonia gonecha (Ach.)Asah.
Cladonia gracilis (L.)Willd. var. *dilatata* (Hoffm.)Vain
Cladonia gracilis (L.)Willd. var. *gracilis* (L.)Willd.
Cladonia lepidota Nyl.
Cladonia macrophylla (Schaer.)Stenh.
Cladonia macrophyllodes Nyl.
Cladonia major (Hag.)Sandst.
Cladonia metacorallifera Asahina
Cladonia mitis Sandst.
Cladonia norrlini Vain.
Cladonia phyllophora (Ehrh.)Hoffm.
Cladonia pleurota (Florke)Schaer.
Cladonia pocillum (Ach.)O.Rich
Cladonia polydactyla (Florke)Spreng.
Cladonia pyxidata (L.)Hoffm.
Cladonia rangiferina (L.)Web.
Cladonia squamosa (Scop.)Hoffm.
Cladonia stellaris (Opiz)Pouz.& Vezda
Cladonia subfurcata (Nyl.)Arn.
Cladonia subulata (L.)Wigg.
Cladonia uncialis (L.)Web.

Cladonia verticillata (Hoffm.)Schaer.

COLLEMATACEAE
Collema sp.

LECANORACEAE
Haematomma lapponicum Raes.
Icmadophila ericetorum (L.)Zahlbr.
Lecanora epibyron (Ach.)Ach.
Lecanora intricata (Schrad.)Ach.
Lecanora urceolaria (Fr.)Wetm.
Ochrolechia sp.
Ochrolechia androgyna (Hoffm.)Arn.
Ochrolechia geminipara (Th.Fr.)Vain.
Ochrolechia inaequatula (Nyl.)Zahlbr.
Ochrolechia uliginosa L.

LECIDEACEAE
Bacidia alpina (Schaer.)Vain.
Bacidia bagliettoana (Mass.&DeNot.)Jatta
Lecidea sp.
Lecidea auriculata Th.Fr.
Lecidea crustulata (Ach.)Spreng.
Lecidea demissa (Rutstr.)Ach.
Lecidea flavocaerulescens Hornem.
Lecidea glaucophaea Korb.
Lecidea granulosa (Ehrh.)Ach.
Lecidea hypocrita Mass.
Lecidea jurana Schaer.
Lecidea limosa Ach.
Lecidea macrocarpa (DC.)Steud.
Lecidea pantherina (Hoffm.)Th.Fr.
Lecidea vernalis (L.)Ach.
Lecidella stigmatea (Ach.)Herb.& Leuck.
Rhizocarpon sp.
Rhizocarpon chioneum (Norm.)Th.Fr.
Rhizocarpon eupetraeoides (Nyl.)Blomb.
Rhizocarpon geographicum (L.)DC.
Rhizocarpon inarense (Vain.)Vain.
Rhizocarpon intermediellum Ras.
Rhizocarpon riparium Ras.
Rhizocarpon umbilicatum (Ram.)Jatta
Toninia lobulata (Somm.)Lunge
Toninia tristis (Th.Fr.)Th.Fr.

LEPRARIACEAE
Lepraria neglecta L.

NEPHROMATACEAE
Nephroma arcticum (L.)Torss.
Nephroma expallidum Nyl.

PANNARIACEAE
Pannaria pezizoides (Web.)Trev.
Pannaria rubiginosa (Thunb.ex.Ach.)Del.
Psoroma hypnorum (Vahl)S.F.Gray

PARMELIACEAE
Asahinea chrysantha (Tuck.)W.Culb.& C.Culb.
Cetraria sp.
Cetraria commixta (Nyl.)Th.Fr.
Cetraria cucullata (Bell.)Arg.
Cetraria delisei (Bory)Th.Fr.

Cetraria ericetorum Opiz
Cetraria hepatizon (Ach.)Vain.
Cetraria islandica (L.)Ach.
Cetraria laevigata Rass.
Cetraria nivalis (L.)Ach.
Cetraria pinastri (Scop.)S.Gray
Cetraria richardsonii Hook.
Cetraria sepincola (Ehrh.)Ach.
Cetraria subalpina Imsch.
Cetraria tilesii Ach.
Hypogymnia oroarctica Krog
Parmelia centifuga (L.)Ach.
Parmelia separata Th.Fr.
Parmelia septentrionalis (Lynge)Ahti
Parmeliopsis sp.
Parmeliopsis ambigua (Wulf.)Nyl.
Parmeliopsis hyperota (Ach.)Arn.

PELTIGERACEAE
Peltigera sp.
Peltigera aphthosa (L.)Willd.
Peltigera canina (L.)Willd.
Peltigera malacea (Ach.)Funck
Peltigera polydactyla (Neck.)Hoffm.
Peltigera pulverulenta (Tayl.)Kremph.
Peltigera rufescens (Weis.)Humb.
Peltigera spuria (Ach.)DC.
Peltigera venosa (L.)Baumg.
Solarina sp.
Solarina bispora Nyl.
Solarina crocea (L.)Ach.
Solarina saccata (L.)Ach.

PERTUSARIACEAE
Pertusaria dactylina (Ach.)Nyl.

PHYSCIACEAE
Physcia caesia (Hoffm.)Hampe

SPHAEROPHORACEAE
Sphaerophorous globosus (Huds.)Vain.

STEREOCAULACEAE
Stereocaulon sp.
Stereocaulon alpinum Laur.
Stereocaulon condensatum Hoffm.
Stereocaulon dactylophyllum Floerke
Stereocaulon glareosum (Savicz)Magn.
Stereocaulon paschale (L.)Hoffm.
Stereocaulon rivulorum Magn.
Stereocaulon saxatile Magn.
Stereocaulon tomentosum Fr.

UMBILICARIACEAE
Agyrophora rigida (DuReitz)Llano
Omphalodiscus decussatus (Vill.)Schol.
Omphalodiscus krascheninnikovii (Savicz)Schol.
Omphalodiscus virginis (Schaer.)Schol.
Umbilicaria sp.
Umbilicaria hyperborea (Ach.)Hoffm.
Umbilicaria hyperborea (Ach.)Hoffm. var. *radiculata* Zett.
Umbilicaria proboscidea (L.)Schrad.
Umbilicaria torrefacta (Lightf.)Schrad.

USNEACEAE
Alectoria ochroleuca (Hoffm.)Mass.
Cornicularia aculeata (Schreb.)Ach.
Cornicularia divergens Ach.
Dactylina arctica (Hook.)Nyl.
Dactylina beringica Thoms.& Bird
Dactylina ramulosa (Hook.)Tuck.
Evernia perfragilis Llano
Thamnolia subuliformis (Ehrh.)W.Culb.
Thamnolia vermicularis (Sw.)Schaer.

VERRUCARIACEAE
Polyblastia sp.
Polyblastia gelatinosa (Ach.)Th.Fr.
Polyblastia gothica Th.Fr.
Polyblastia hyperborea Th.Fr.
Polyblastia integrascens (Nyl.)Vain.
Polyblastia sendtneri Kremp
Polyblastia theleodes (Somm.)Th.Fr.
Thelidium aeneovinosum (Anzi)Arn.
Verrucaria aethiobola Wahlenb.ex.Ach.
Verrucaria muralis Ach.

NON-VASCULAR PLANTS: BRYOPHYTES

AMBLYSTEGIACEAE
Calliergon sarmentosum (Wahlenb.)Kindb.
Calliergon stramineum (Brid.)Kindb.
Campylium chrysophyllum (Brid.)J.Lange
Campylium polygamum (B.S.G.)C.Jens.
Campylium stellatum (Hedw.)C.Jens.
Campylium stellatum (Hedw.)C.Jens. var. *arcticum* (Williams)Sav.–Ljub.
Cratoneuron commutatum (Hedw.)Roth
Drepanocladus sp.
Drepanocladus exannulatus (B.S.G.)Warnst.
Drepanocladus revolvens (Sw.)Warnst.
Drepanocladus sendtneri (Schimp.)Warnst.
Drepanocladus uncinatus (Hedw.)Warnst.
Platydictya jungermannioides (Brid.)Crum

ANDREACEAE
Andrea rupestris Hedw.

AULACOMNIACEAE
Aulacomnium sp.
Aulacomnium acuminatum (Lindb.& Arn.)Kindb.
Aulacomnium palustre (Hedw.)Schwaegr.
Aulacomnium turgidum (Wahlenb.)Schwaegr.

BARTRAMIACEAE
Bartramia ithyphylla Brid.
Conostomum tetragonum (Hedw.)Lindb.
Philonotis fontana (Hedw.)Brid.
Philonotis tomentella Mol.

BRACHYTHECIACEAE
Brachythecium sp.
Brachythecium erythrorrhizon B.S.G.
Brachythecium groenlandicum (C.Jens.)Schljak.
Brachythecium salebrosum (Web.& Mohr)B.S.G.
Brachythecium starkei (Brid.)B.S.G.
Brachythecium turgidum (C.J.Hartm.)Kindb.
Cirriphyllum cirrosum (Schwaegr.ex.Schultes)Grout
Tomenthypnum sp.
Tomenthypnum nitens (Hedw.)Loeske

BRYACEAE
Bryum sp.
Bryum bimum (Brid.)Turn.
Bryum pseudotriquetrum (Hedw.)Gaert.
Bryum tortifolium Funck ex.Brid.
Pohlia sp.
Pohlia cruda (Hedw.)Lindb.
Pohlia nutans (Hedw.)Lindb.

CATASCOPIACEAE
Catascopium nigritum (Hedw.)Brid.

CLIMACIACEAE
Climacium dendroides (Hedw.)Web.& Mohr

DICRANACEAE
Dicranum sp.
Dicranum elongatum Schleich.ex.Schwaegr.
Dicranum pallidisetum (Bail.ex.Holz.)Irel.
Oncophorus virens (Hedw.)Brid.

DITRICHACEAE
Ceratodon purpureus (Hedw.)Brid.
Distichium sp.
Distichium capillaceum (Hedw.)B.S.G.
Distichium inclinatum (Hedw.)B.S.G.
Ditrichum sp.
Ditrichum flexicaule (Schwaegr.)Hampe

ENCALYPTACEAE
Encalypta sp.
Encalypta affinis R.Hedw.
Encalypta alpina Smith
Encalypta procera Bruch

ENTODONTACEAE
Orthothecium cryseum (Schwaegr.ex.Schultes)B.S.G.
Orthothecium strictum Lor.
Pleurozium schreberi (Brid.)Mitt.

FISSIDENTACEAE
Fissidens osmundoides Hedw.

FUNARIACEAE
Funaria hygrometrica Hedw.

GRIMMIACEAE
Grimmia sp.
Rhacomitrium canescens (Hedw.)Brid.
Rhacomitrium lanuginosum (Hedw.)Brid.
Schistidium sp.

HYLOCOMNIACEAE
Hylocomnium splendens (Hedw.)B.S.G.

HYPNACEAE
Hypnum sp.
Hypnum bambergii Schimp.
Hypnum cupressiforme Hedw.
Hypnum lindbergii Mitt.
Hypnum procerrimum Mol.
Hypnum revolutum (Mitt.)Lindb.
Ptilium crista-castrensis (Hedw.)De-Not.

LESKEACEAE
Lescuraea radicosa (Mitt.)Monk.

MEESIACEAE
Paludella squarrosa (Hedw.)Brid.

MNIUMACEAE
Cinclidium stygium Sw.
Cyrtomnium sp.
Cyrtomnium hymenophyllum (B.S.G.)Kop.
Plagiomnium cuspidatum (Hedw.)Kop.
Plagiomnium ellipticum (Brid.)Kop.
Plagiomnium medium (B.S.G.)Kop.
Rhizomnium sp.
Rhizomnium pseudopunctatum (Bruch & Schimp.)Kop.
Rhizomnium punctatum (Hedw.)Kop.

ORTHOTRICHACEAE
Orthotrichum sp.

POLYTRICHACEAE
Oligotrichum sp.
Pogonatum alpinum (Hedw.)Rohl.
Pogonatum dentatum (Brid.)Brid.
Pogonatum urnigerum (Hedw.)Beauv.
Polytrichum sp.
Polytrichum commune Hedw.
Polytrichum hyperboreum R.Br.
Polytrichum juniperinum Hedw.
Polytrichum piliferum Hedw.
Polytrichum strictum Brid.

POTTIACEAE
Bryoerythrophyllum recurvirostrum (Hedw.)Chen
Desmatadon sp.
Desmatadon latifolius (Hedw.)Brid.
Tortella arctica (H.Arn.)Crundwell & Nyholm
Tortella fragilis (Drumm.)Limpr.
Tortella inclinata (Hedw.)Limpr.
Tortella rigens N.Albertson
Tortella tortuosa (Hedw.)Limpr.
Tortula latifolia Bruch ex.C.J.Hartm.
Tortula mucronifolia Schwaegr.
Tortula norvegica (Web.)Wahlenb.ex.Lindb.
Tortula ruralis (Hedw.)Gaertn.,Meyer & Scherb.
Trichostomum arcticum Kaal.
Trichostomum crispulum Bruch
Weisia controversa Hedw.

PTILIDIACEAE
Blepharostoma sp.

RHYTIDIACEAE
Rhytidium rugosum (Sull.)Kindb.

SPHAGNACEAE
Sphagnum sp.

SPLACHNACEAE
Tetraplodon mnioides (Hedw.)B.S.G.
Tetraplodon paradoxus (R.Br.)Hag.

THELIACEAE
Myurella julacea (Schwaegr.)B.S.G.

THUIDIACEAE
Abietinella abietina (Hedw.)Fleisch

VASCULAR PLANTS

BETULACEAE
Alnus crispa (Ait.)Pursh
Betula glandulosa Michx.

BORAGINACEAE
Mertensia paniculata (Ait.)G.Don
Myosotis alpestris F.W.Schmidt ssp. *asiatica* Vestergr.

CALLITRICHACEAE
Callitriche verna L.

CAMPANULACEAE
Campanula lasiocarpa Cham.
Campanula uniflora L.

CAPRIFOLIACEAE
Linnaea borealis L. var. *americana* (Forbes)Rehd.

CARYOPHYLLACEAE
Arenaria humifusa Wahlenb.
Cerastium beeringianum Cham.& Schlecht.
Melandrium apetalum (L.)Frezl
Minuartia arctica (Stev.)Aschers & Graebn.
Minuartia biflora (L.)Schinz & Thell.
Minuartia macrocarpa (Pursh)Ostenf.
Minuartia rossii (R.Br.)House
Minuartia rubella (Wahlenb.)Hiern.
Minuartia stricta (Sw.)Hiern.
Moehringia lateriflora (L.)Fenzl
Sagina intermedia Fenzl
Sagina linnaei Presl
Silene acaulis L.
Stellaria edwardsii R.Br.
Stellaria laeta Richards.
Stellaria longipes Goldie
Stellaria monantha Hult.

CHENOPODIACEAE
Chenopodium capitatum (L.)Asch.

COMPOSITAE
Achillea lanulosa Nutt.
Agoseris aurantiaca (Hook.)Greene
Antennaria densifolia Porsild
Antennaria ekmaniana Porsild
Antennaria isolepis Greene
Antennaria monocephala DC.
Antennaria nitida Greene
Antennaria stolonifera Porsild
Arnica alpina (L.)Olin ssp. *angustifolia* (J.Vahl)Maguire
Arnica lessingii Greene
Arnica louiseana Farr. ssp. *frigida* (Mey.ex Iljin)Maguire
Artemisia arctica Less.
Artemisia tilesii Ledeb. var. *tilesii*
Artemisia tilesii Ledeb. var. *elatior* T.& G.
Aster alpinus L. ssp.*vierhapperi* Onno
Aster sibiricus L.
Chrysanthemum integrifolium Richards.
Crepis nana Richards.
Erigeron acris L. var. *debilis* Gray
Erigeron eriocephalus J.Vahl
Erigeron humilis Graham

Erigeron hyperboreus Greene
Erigeron purpuratus Greene
Hieracium triste Willd.
Petasites frigidus (L.)Fries
Petasites hyperboreus Rydb.
Petasites palmatus (Ait.)Gray
Saussurea angustifolia (Willd.)DC.
Senecio atropurpureus (Ledeb.)Fedtsch.
Senecio cymbalaria Pursh
Senecio kjellmanii Porsild
Senecio lugens Richards.
Senecio triangularis Hook.
Senecio yukonensis Porsild
Solidago multiradiata Ait.
Taraxacum alaskanum Rydb.
Taraxacum officinale Weber
Taraxacum maurolepium Hagl.

CORNACEAE
Cornus canadensis L.

CRASSULACEAE
Rhodiola integrifolia Raf.

CRUCIFERAE
Arabis divaricarpa A Nels.
Arabis drummondii Gray
Arabis lyrata L. var. *kamchatica Fisch.*
Brassica campestris L.
Braya purpurascens (R.Br.)Bge
Braya richardsonii (Rydb.)Fern.
Cardamine bellidifolia L.
Cardamine pratensis L.
Cardamine umbellata Greene
Descuriana richardsonii (Sweet)Schulz
Draba albertina Greene
Draba alpina L.
Draba borealis DC.
Draba cana Rydb.
Draba corymbosa R.Br.
Draba crassifolia Grah.
Draba glabella Pursh
Draba lactea Adams
Draba longipes Raup
Draba ogilviensis Hult.
Draba nivalis Lilijebl.
Draba porsildii G.A.Mulligan
Draba praealta Greene
Erysimum cheiranthoides L.
Eutrema edwardsii R.Br.
Lepidium densiflorum Schrad.
Lesquerella arctica (Wormsk.)S.Wats.
Parrya nudicaulis (L.)Regel
Smelowskia borealis (Greene)Drury & Rollins
Thlaspi arvense L.

CYPERACEAE
Carex aquatilis Wahlenb. var. *aquatilis*
Carex aquatilis Wahlenb. var. *stans* (Drej.)Boott
Carex atrofusca Schk.
Carex atrosquama Mack.
Carex aurea Nutt.
Carex brunnescens (Pers.)Poir.

Carex capillaris L.
Carex concinna R.Br.
Carex deflexa Hornem.
Carex glacialis Mack.
Carex gynocrates Wormskj.
Carex lachenalii Schk.
Carex lugens Holm
Carex macloviana D'Urv
Carex membranacea Hook.
Carex microchaeta Holm
Carex microglochin Wahlenb.
Carex misandra R.Br.
Carex nardina E.Fries
Carex petricosa Dewey
Carex phaeocephala Piper
Carex podocarpa R.Br.
Carex pyrenaica Wahlenb. ssp. *micropoda* (C.A.Mey.)Hult.
Carex rupestris All.
Carex saxatilis L. var. *rhomalea* Fern.
Carex scirpoidea Michx.
Carex vaginata Tausch
Eriophorum angustifolium Honck.
Eriophorum callitrix Cham.
Eriophorum russeolum Fries var. *albidum* Nyl.
Eriophorum scheuchzeri Hoppe
Eriophorum vaginatum L.
Kobresia myosuroides (Vill.)Fiorni & Paol.
Kobresia simpliciuscula (Wahlenb.)Mack.
Scirpus caespitosus L. ssp. *austriacus* (Pallas)Asch.& Graeb.

ELAEAGNACEAE
Shepherdia canadensis (L.)Nutt.

EMPETRACEAE
Empetrum nigrum L. ssp. *hermaphroditicum* (Lange)Bocher

EQUISETACEAE
Equisetum arvense L.
Equisetum palustre L.
Equisetum scirpoides Michx.
Equisetum sylvaticum L. var. *pauciramosum* Milde
Equisetum variegatum Schleich.

ERICACEAE
Andromeda polifolia L.
Arctostaphylos alpina (L.)Spreng.
Arctostaphylos uva-ursi (L.)Spreng.
Cassiope tetragona (L.)D.Don
Kalmia polifolia Wang.
Ledum decumbens (Ait.)Lodd.
Ledum groenlandicum Oeder
Loisleuria procumbens (L.)Desv.
Phyllodoce empetriformis (Sm.)D.Don
Rhododendron lapponicum (L.)Wahlenb.
Vaccinium uliginosum L.
Vaccinium vitis-idaea L. var. *minus* Lodd

FUMARIACEAE
Corydalis pauciflora (Steph.)Pers.

GENTIANACEAE
Gentiana glauca Pall.
Gentiana propinqua Richards.

Gentiana prostrata Haenke
Gentiana raupii Porsild

GRAMINEAE
Agropyron violaceum (Hornem.)Lge.
Agrostis scabra Willd.
Agrostis stolonifera L.
Alopecurus alpinus J.E.Smith
Arctagrostis arundinacea (Trin.)Beal
Arctagrostis latifolia (R.Br.)Griseb.
Calamagrostis canadensis (Michx.)Beauv. var. *langsdorfii* (Link)Inman
Calamagrostis lapponica (Wahlenb.)Hartm. var. *nearctica* Porsild
Calamagrostis purpurascens R.Br.
Deschampsia brevifolia R.Br.
Deschampsia caespitosa (L.)Beauv.
Elymus innovatus Beal
Festuca altaica Trin.
Festuca baffinensis Polunin
Festuca brachyphylla Schultes
Festuca rubra L. ssp. *richardsonii* (Hook.)Hult.
Hierochloe alpina (Swartz)R.& S.
Hierochloe odorata (L.)Beauv.
Hordeum jubatum L.
Phleum commutatum Gaud.
Poa alpigena (Fries)Lindm.
Poa alpina L.
Poa arctica R.br.
Poa glauca M.Vahl
Poa porsildii Gjaerevoll
Poa pratensis L.
Trisetum spicatum (L.)Richter
Triticum aestivum L.

HALORAGACEAE
Hippuris vulgaris L.

JUNCACEAE
Juncus albescens (Lange)Fern.
Juncus balticus L.
Juncus biglumis L.
Juncus castaneus Smith
Luzula arcuata (Wahlenb.)Sw.
Luzula confusa Lindb.
Luzula multiflora (Retz.)Lej.
Luzula nivalis (Laest.)Beurl.
Luzula parviflora (Ehrh.)Desv.
Luzula spicata (L.)DC.

JUNCAGINACEAE
Triglochin maritimum L.
Triglochin palustris L.

LEGUMINOSAE
Astragalus alpinus L.
Astragalus umbellatus Bunge
Hedysarum alpinum L. var. *americanum* Michx.
Hedysarum mackenzii Richards.
Lupinus arcticus S.Wats.
Oxytropis deflexa (Pall.)DC. var. *foliosa* (Hook.)Barneby
Oxytropis jordalii Porsild
Oxytropis maydelliana Trautv.
Oxytropis nigrescens (Pall.)Fisch.
Oxytropis sheldonensis Porsild

LENTIBULARIACEAE
Pinguicula vulgaris L.

LILIACEAE
Lloydia serotina (L.)Rchb.
Tofieldia coccinea Richards.
Tofieldia pusilla (Michx.)Pers.
Veratrum eschscholtzii A.Gray
Zygadenus elegans Pursh

LYCOPODIACEAE
Lycopodium alpinum L.
Lycopodium annotinum L.
Lycopodium clavatum L. var. *monostachyon* Grev.&Hook.
Lycopodium selago L.

ONAGRACEAE
Epilobium anagallidifolium Lam.
Epilobium angustifolium L.
Epilobium latifolium L.
Epilobium palustre L.

OPHIOGLOSSACEAE
Botrychium lunaria (L.)Sw.

ORCHIDACEAE
Corallorrhiza trifida Chatelain
Cypripedium passerinum Richards.
Habenaria hyperborea (L.)R.Br.

PAPAVERACEAE
Papaver keelei Porsild
Papaver radicatum Rottb.

PINACEAE
Abies lasiocarpa (Hook.)Nutt.
Juniperus communis L.
Picea glauca (Moench)Voss

PLUMBAGINACEAE
Armeria maritima (Mill.)Willd.

POLEMONIACEAE
Polemonium acutiflorum Willd.
Polemonium boreale Adams

POLYGONACEAE
Oxyria digyna (L.)Hill
Polygonum bistorta L. ssp. *plumosum* (Small)Hult.
Polygonum viviparum L.
Rumex arcticus Trautv.
Rumex occidentalis Wats.

POLYPODIACEAE
Cystopteris fragilis (L.)Bernh.
Dryopteris fragrans (L.)Schott
Dryopteris robertiana (Hoffm.)C.Chr.
Woodsia glabella R.Br.

PORTULACACEAE
Claytonia megarrhiza (Gray)Parry
Claytonia tuberosa Pall.

PRIMULACEAE
Androsace chamaejasme Host var. *arcticus* Knuth
Primula egaliksensis Wormsk.

PYROLACEAE
Pyrola asarifolia Michx.
Pyrola grandiflora Radius
Pyrola minor L.
Pyrola secunda L.

RANUNCULACEAE
Aconitum delphinifolium DC.
Anemone drummondii S.Wats.
Anemone narcissiflora L.
Anemone parviflora Michx.
Anemone richardsonii Hook.
Delphinium glaucum S.Wats.
Ranunculus eschscholtzii Schlecht.
Ranunculus hyperboreus Rottb.
Ranunculus nivalis L.
Ranunculus pygmaeus Wahlenb.
Ranunculus sulphureus Sol.
Thalictrum alpinum L.

ROSACEAE
Dryas crenulata Juz.
Dryas drummondii Richards.
Dryas hookeriana Juz.
Dryas integrifolia M.Vahl
Dryas octopetala L.
Dryas sylvatica (Hult.)Porsild
Geum macrophyllum Willd. ssp. *perincisum* (Rydb.)Raup
Geum rossii (R.Br.)Ser.
Potentilla biflora Willd.
Potentilla diversifolia Lehm. ssp. *glaucophylla* Lehm.
Potentilla elegans Cham.& Schlecht.
Potentilla fruticosa L.
Potentilla hyparctica Malte var. *elatior* (Abrom.)Fern.
Potentilla nivea L. ssp. *chamissonis* (Hult.)Hiit.
Potentilla norvegica L.
Potentilla palustris (L.)Scop.
Potentilla rubricaulis Lehm.
Potentilla uniflora Ledeb.
Potentilla vahliana Lehm.
Rosa acicularis Lindl.
Rubus acaulis Michx.
Rubus chamaemorus L.
Sibbaldia procumbens L.
Spiraea beauverdiana Schneid.

RUBIACEAE
Galium trifidum L.

SALICACEAE
Populus balsamifera L.
Populus tremuloides Michx.
Salix alaxensis (Anderss.)Cov.
Salix arbusculoides Anderss.
Salix arctica Pall.
Salix arctica x *S. polaris*
Salix arctophila Cockerell
Salix barclayi Anderss.
Salix barrattiana Hook.

Salix commutata Bebb
Salix dodgeana Rydb.
Salix glauca L.
Salix lanata L. ssp. *richardsonii* (Hook.)Skvortz.
Salix myrtillifolia Anderss.
Salix planifolia Pursh
Salix polaris Wahlenb. ssp. *pseudopolaris* (Flod.)Hult.
Salix reticulata L.

SAXIFRAGACEAE
Chrysosplenium tetrandrum (Lund.)T.Fries
Leptarrhena pyrolifolia (D.Don)Ser.
Parnassia fimbriata Koenig
Parnassia kotzbuei Cham.& Schlecht.
Parnassia palustris L. ssp. *neogaea* Hult.
Saxifraga aizoides L.
Saxifraga cernua L.
Saxifraga davurica Willd. ssp. *grandipetala* (Engl.& Irmsch)Hult.
Saxifraga flagellaris Willd.
Saxifraga foliosa R.br.
Saxifraga hieracifolia Waldst.& Kit.
Saxifraga hirculus L. var. *propinqua (R.Br.)Simm.*
Saxifraga oppositifolia L.
Saxifraga punctata L.
Saxifraga radiata Small
Saxifraga reflexa Hook.
Saxifraga rivularis L.
Saxifraga serpyllifolia Pursh
Saxifraga tricuspidata Rottb.

SCROPHULARIACEAE
Castilleja caudata (Pennell)Rebr.
Lagotis stelleri (Cham.& Schlecht.)Rupr.
Pedicularis arctica R.Br.
Pedicularis capitata Adams
Pedicularis labradorica Wirsing
Pedicularis lanata Cham.& Schlecht.
Pedicularis sudetica Willd.
Veronica wormskjoldii Roem.& Schult.

SELAGINELLACEAE
Selaginella selaginoides (L.)Link

VALERIANACEAE
Valeriana capitata Pall.

VIOLACEAE
Viola epipsila Ledeb. ssp. *repens* (Turcz.)Becker

APPENDIX V: COVER DIFFERENCES FROM CONTROLS FOR PLANTS ON CANOL DISTURBANCES

Alphabetical Listing of Plant Abbreviations

ABI ABIE=*Abietinella abietina*
ABI LASI=*Abies lasiocarpa*
ACA SCHL=*Acarospora schleicheri*
ACH LANU=*Achillea lanulosa*
ACO DELP=*Aconitum delphinifolium*
AGO AURA=*Agoseris aurantiaca*
AGR ALBA=*Agrostis alba (=A.stolonifera)*
AGR VIOL=*Agropyron violaceum*
AGS SCAB=*Agrostis scabra*
AGY RIGI=*Agyrophora rigida*
ALE OCHR=*Alectoria ochroleuca*
ALN CRIS=*Alnus crispa*
ALO ALPI=*Alopecurus alpinus*
AMBLYSTE=Amblystegiaceae
AND CHAM=*Androsace chamaejasme*
AND POLI=*Andromeda polifolia*
AND RUPE=*Andrea rupestris*
ANE DRUM=*Anemone drummondii*
ANE NARC=*Anemone narcissiflora*
ANE PARV=*Anemone parviflora*
ANE RICH=*Anemone richardsonii*
ANT DENS=*Antennaria densifolia*
ANT EKMA=*Antennaria ekmaniana*
ANT ISOL=*Antennaria isolepis*
ANT MONO=*Antennaria monocephala*
ANT NITI=*Antennaria nitida*
ANT STOL=*Antennaria stolonifera*
ANTEN SP=*Antennaria species* (singular)
ARA DIVA=*Arabis divaricarpa*
ARA DRUM=*Arabis drummondii*
ARA LYRA=*Arabis lyrata*
ARC ALPI=*Arctostaphylos alpina*
ARC LATI=*Arctagrostis latifolia*
ARC UVA-=*Arctostaphylos uva-ursi*
ARE HUMI=*Arenaria humifusa*
ARM MARI=*Armeria maritima*
ARN ALPI=*Arnica alpina*
ARN LOUI=*Arnica louiseana*
ARN LESS=*Arnica lessingii*
ART ARCT=*Artemisia arctica*
ART T EL=*Artemisia tilesii elatior*
ART TILE=*Artemisia tilesii tilesii*
ASA CHRY=*Asahinea chrysantha*
ASR ALPI=*Astragalus alpinus*
AST ALPI=*Aster alpinus*
AST SIBI=*Aster sibiricus*
AST UMBE=*Astragalus umbellatus*
ASTRA SP=*Astragalus species* (singular)
AUL ACUM=*Aulacomnium acuminatum*
AUL PALU=*Aulacomnium palustre*
AUL TURG=*Aulacomnium turgidum*
AULAC SP=*Aulacomnium* species (singular)
BAC ALPI=*Bacidia alpina*
BAC BAGL=*Bacidia bagliettoana*
BAE CARN=*Baeomyces carneus*
BAE ROSE=*Baeomyces roseus*
BAE RUFU=*Baeomyces rufus*
BAR ITHY=*Bartramia ithyphylla*
BASIDIOM=Basidiomycete(s)
BET GLAN=*Betula glandulosa*
BET PUMI=*Betula pumila glandulifera*
BETULA =*Betula* species (singular)
BLE TRIC=*Blepharostema trichophylla*
BOT LUNA=*Botrychium lunaria*
BRA CAMP=*Brassica campestris*
BRA ERYT=*Brachythecium erythrorrhizon*
BRA GROE=*Brachythecium groenlandicum*
BRA PURP=*Braya purpurascens*
BRA RICH=*Braya richardsonii*
BRA SALE=*Brachythecium salebrosum*
BRA STAR=*Brachythecium starkei*
BRA TURG=*Brachythecium turgidum*
BRACH SP=*Brachythecium* species (singular)
BRY BIMU=*Bryum bimum*
BRY PSEU=*Bryum pseudotriquetrum*
BRY RECU=*Bryoerythrophyllum recurvirostrum*
BRY TORT=*Bryum tortifolium*
BRYACEAE=Bryaceae
BRYUM SP=*Bryum* species (singular)
BUE DISC=*Buellia disciformis*
BUE IMME=*Buellia immersa*
BUE SCAB=*Buellia scabrosa*
CAL CANA=*Calamagrostis canadensis*
CAL LAPP=*Calamagrostis lapponica*
CAL PURP=*Calamagrostis purpurascens*
CAL SARM=*Calliergon sarmentosum*
CAL STRA=*Calliergon stramineum*
CAL VERN=*Callitriche verna*
CAM CHRY=*Campylium chrysophyllum*
CAM LASI=*Campanula lasiocarpa*
CAM POLI=*Campylium polygamum*
CAM S AR=*Campylium stellatum arcticum*
CAM STEL=*Campylium stellatum*
CAM UNIF=*Campanula uniflora*
CAR A AQ=*Carex aquatilis aquatilis*
CAR A ST=*Carex auqatilis stans*
CAR ATSQ=*Carex atrosquama*
CAR ATFU=*Carex atrofusca*
CAR AURE=*Carex aurea*
CAR BELL=*Cardamine bellidifolia*
CAR BRUN=*Carex brunnescens*
CAR CAPI=*Carex capillaris*
CAR CONC=*Carex concinna*
CAR DEFL=*Carex deflexa*
CAR GYNO=*Carex gynocrates*
CAR GLAC=*CArex glacialis*
CAR LACH=*Carex lachenalii*
CAR LUGE=*Carex lugens*
CAR MACL=*Carex macloviana*
CAR MEMB=*Carex membranacea*
CAR MICH=*Carex microchaeta*
CAR MICG=*Carex microglochin*
CAR MISA=*Carex misandra*
CAR NARD=*Carex nardina*
CAR PETR=*Carex petricosa*
CAR PHAE=*Carex phaeocephala*
CAR PODO=*Carex podocarpa*
CAR PRAT=*Cardamine pratensis*
CAR PYRE=*Carex pyrenaica*
CAR RUPE=*Carex rupestris*
CAR SAXA=*Carex saxatilis*
CAR SCIR=*Carex scirpoidea*
CAR UMBE=*Cardamine umbellata*
CAR VAGI=*Carex vaginata*
CAREX SP=*Carex* species (singular)
CAS CAUD=*Castilleja caudata*
CAS TETR=*Cassiope tetragona*
CASTI SP=*Castilleja* species (singular)
CAT NIGR=*Catascopium nigritum*
CER BEER=*Cerastium beeringianum*
CER PURP=*Ceratodon purpureus*
CET COMM=*Cetraria commixta*
CET CUCU=*Cetraria cucullata*
CET DELI=*Cetraria delisei*
CET ERIC=*Cetraria ericetorum*
CET HEPA=*Cetraria hepatizon*
CET ISLA=*Cetraria islandica*
CET LAEV=*Cetraria laevigata*
CET NIVA=*Cetraria nivalis*
CET PINA=*Cetraria pinastri*
CET RICH=*Cetraria richardsonii*
CET SEPI=*Cetraria sepincola*
CET SUBA=*Cetraria subalpina*
CET TILE=*Cetraria tilesii*

Alphabetical Listing Continued

CETRA SP=*Cetraria* species (singular)
CHE CAPI=*Chenopodium capitatum*
CHR INTE=*Chrysanthemum integrifolium*
CHR TETR=*Chrysosplenium tetrandrum*
CIN STYG=*Cinclidium stygium*
CIR CIRR=*Cirriphyllum cirrosum*
CLA ACUM=*Cladonia acuminata*
CLA AMAU=*Cladonia amauracraea*
CLA ARBU=*Cladonia arbuscula*
CLA BACF=*Cladonia bacillariformis*
CLA BACL=*Cladonia bacillaris*
CLA BELL=*Cladonia bellidiflora*
CLA BOTR=*Cladonia botrytes*
CLA CARI=*Cladonia cariosa*
CLA CARN=*Cladonia carneola*
CLA CENO=*Cladonia cenotea*
CLA CHLO=*Cladonia chlorophaea*
CLA COCC=*Cladonia coccifera*
CLA CORN=*Cladonia cornuta*
CLA CRIS=*Cladonia crispata*
CLA DECO=*Cladonia decorticata*
CLA DEFO=*Cladonia deformis*
CLA ECMO=*Cladonia ecmocyna*
CLA FIMB=*Cladonia fimbriata*
CLA FURC=*Cladonia furcata*
CLA G DI=*Cladonia gracilis dilatata*
CLA G GR=*Cladonia gracilis gracilis*
CLA GONE=*Cladonia gonecha*
CLA GRAC=*Cladonia gracilis*
CLA LEPI=*Cladonia lepidota*
CLA MACA=*Cladonia macrophylla*
CLA MACR=*Cladonia macrophyllodes*
CLA MAJO=*Cladonia major*
CLA MEGA=*Claytonia megarrhiza*
CLA META=*Cladonia metacorallifrea*
CLA MITI=*Cladonia mitis*
CLA NORR=*Cladonia norrlini*
CLA PHYL=*Cladonia phyllophora*
CLA PLEU=*Cladonia pleurota*
CLA POCI=*Cladonia pocillum*
CLA POLY=*Cladonia polydactyla*
CLA PYXI=*Cladonia pyxidata*
CLA RANG=*Cladonia rangiferina*
CLA SQUA=*Cladonia squamosa*
CLA STEL=*Cladonia stellaris*
CLA SUBF=*Cladonia subfurcata*
CLA SUBU=*Cladonia subulata*
CLA TUBE=*Claytonia tuberosa*
CLA UNCI=*Cladonia uncialis*
CLA VERT=*Cladonia verticillata*

CLAD SPP=*Cladonia* species (plural)
CLADINA =*Cladonia* species (fruticose)
CLADO SP=*Cladonia* species (singular)
CLI DEND=*Climacium dendroides*
COLLEMA =*Collema* species (singular)
COMPO SP=Compositae species (singular)
CON TETR=*Conostomum tetragonum*
COR ACUL=*Cornicularia aculeata*
COR CANA=*Cornus canadensis*
COR DIVE=*Cornicularia divergens*
COR PAUC=*Corydalis pauciflora*
COR TRIF=*Corallorrhiza trifida*
CRA COMM=*Cratoneuron commutatum*
CRE NANA=*Crepis nana*
CRUCIFER=Cruciferae species (singular)
CRUSTOSE=Crustose Lichens (sing.or plural)
CYP PASS=*Cypripedium passerinum*
CYR HYME=*Cyrtomnium hymenophyllum*
CYRTOMNI=*Cyrtomnium* species (singular)
CYS FRAG=*Cystopteris fragilis*
DAC ARCT=*Dactylina arctica*
DAC BERI=*Dactylina beringica*
DAC RAMU=*Dactylina ramulosa*
DACTYLIN=*Dactylina* species (singular)
DEL GLAU=*Delphinium glaucum*
DES BREV=*Deschampsia brevifolia*
DES CAES=*Deschampsia caespitosa*
DES LATI=*Desmatadon latifolius*
DES RICH=*Descuriana richardsonii*
DESMATAD=*Desmatadon* species (singular)
DIC ELON=*Dicranum elongatum*
DIC PALL=*Dicranum pallidisetum*
DICRANOI=Dicranaceae species (singular)
DICRANUM=*Dicranum* species (singular)
DIS CAPI=*Distichium capillaceum*
DIS INCL=*Distichium inclinatum*
DISTICHI=*Distichium* species (singular)
DIT FLEX=*Ditrichum flexicaule*
DITRICHA=Ditrichaceae species (singular)
DITRICHU=*Ditrichum* species (singular)
DRA ALBE=*Draba ablertina*
DRA ALPI=*Draba alpina*
DRA BORE=*Draba borealis*
DRA CANA=*Draba cana*
DRA CORY=*Draba corymbosa*
DRA CRAS=*Draba crassifolia*
DRA GLAB=*Draba glabella*
DRA LACT=*Draba lactea*
DRA LONG=*Draba longipes*
DRA OGLI=*Draba ogilviensis*

DRA NIVA =*Draba nivalis*
DRA PORS =*Draba porsildii*
DRA PRAE =*Draba praealta*
DRABA SP =*Draba* species (singular)
DRE EXAN =*Drepanocladus exannultus*
DRE REVO =*Drepanocladus revolvens*
DRE SEND =*Drepanocladus sendtneri*
DRE UNCI =*Drepanocladus uncinatus*
DREPANOC =*Drepanocladus* species (sing
DRY CREN =*Dryas crenulata*
DRY DRUM =*Dryas drummondii*
DRY FRAG =*Dryopteris fragrans*
DRY HOOK =*Dryas hookeriana*
DRY INTE =*Dryas integrifolia*
DRY OCTO =*Dryas octopetala*
DRY ROBE =*Dryopteris robertiana*
DRY SYLV =*Dryas sylvatica*
ELY INNO =*Elymus innovatus*
EMP NIGR =*Empetrum nigrum*
ENC AFFI =*Encalypta affinis*
ENC ALPI =*Encalypta alpina*
ENC PROC =*Encalypta procera*
ENCALYPT =*Encalypta* species (singular
EPI ANAG =*Epilobium anagallidifoli*
EPI ANGU =*Epilobium angustifolium*
EPI LATI =*Epilobium latifolium*
EPI PALU =*Epilobium palustre*
EPILO SP =*Epilobium* species (singular
EQU ARVE =*Equisetum arvense*
EQU PALU =*Equisetum palustre*
EQU PRAT =*Equisetum pratense*
EQU SCIR =*Equisetum scirpoides*
EQU SYLV =*Equisetum sylvaticum*
EQU VARI =*Equisetum variegatum*
ERI ACRI =*Erigeron acris*
ERI ANGU =*Eriophorum angustifolium*
ERI CALL =*Eriophorum callitrix*
ERI ERIO =*Erigeron eriocephalus*
ERI HUMI =*Erigeron humilis*
ERI HYPE =*Erigeron hyperboreus*
ERI PURP =*Erigeron purpuratus*
ERI RUSS =*Eriophorum russeolum*
ERI SCHE =*Eriophorum scheuchzeri*
ERI VAGI =*Eriophorum vaginatum*
ERIGE SP =*Erigeron* species (singular
ERIOP SP =*Eriophorum* species (singula
ERY CHEI =*Erysimum cheiranthoides*
EUT EDWA =*Eutrema edwardsii*
EVE PERF =*Evernia perfragilis*
FES ALTA =*Festuca altaica*

Alphabetical Listing Continued

FES BAFF=*Festuca baffinensis*
FES BRAC=*Festuca brachyphylla*
FES RUBR=*Festuca rubra*
FIS OSMU=*Fissidens osmundoides*
FUN HYGR=*Funaria hygrometrica*
FUNGI =Fungi species (singular)
GAL TRIF=*Galium trifidum*
GEN GLAU=*Genriana glauca*
GEN PROP=*Gentiana propinqua*
GEN PROS=*Gentiana prostrata*
GEN RAUP=*Gentiana raupii*
GEU MACR=*Geum macrophyllum*
GEU ROSS=*Geum rossii*
GRAMINEA=Gramineae species (singular)
GRIMMIA =*Grimmia* species (singular)
HAB HYPE=*Habenaria hyperborea*
HAE LAPP=*Haematomma lapponicum*
HED ALPI=*Hedysarum alpinum*
HED MACK=*Hedysarum mackenzii*
HEPATICS=Hepatic species
HIE ALPI=*Hierochloe alpina*
HIE ODOR=*Hierochloe odorata*
HIE TRIS=*Hieracium triste*
HIP VULG=*Hippuris vulgaris*
HOR JUBA=*Hordeum jubatum*
HYL SPLE=*Hylocomium splendens*
HYP BAMB=*Hypnum bambergii*
HYP CUPR=*Hypnum cupressiforme*
HYP LIND=*Hypnum lindbergii*
HYP OROA=*Hypogymnia oroarctica*
HYP PROC=*Hypnum procerrimum*
HYP REVO=*Hypnum revolutum*
HYPNUM =*Hypnum* species (singular)
ICM ERIC=*Icmadophila ericetorum*
JUGERMAN= *Jungermaniales*
JUN ALBE=*Juncus albescens*
JUN BALT=*Juncus balticus*
JUN BIGL=*Juncus biglumis*
JUN CAST=*Juncus catsaneus*
JUN COMM=*Juniperus communis*
JUN HORI=*Juniperus horizontalis*
JUNCUS =*Juncus* species (singular)
KAL P MI=*Kalmia polifolia microphylla*
KAL P PO=*Kalmia polifolia polifolia*
KOB MYOS=*Kobresia myosuroides*
KOB SIMP=*Kobresia simpliciuscula*
LAG STEL=*Lagotis stelleri*
LEC AURI=*Lecidea auriculata*
LEC CRUS=*Lecidea crustulata*
LEC EPIB=*Lecanora epibyron*
LEC FLAV=*Lecidea flavocaerulescens*
LEC GLAU=*Lecidea glaucophaea*
LEC GRAN=*Lecidea granulosa*
LEC HYPO=*Lecidea hypocrita*
LEC INTR=*Lecanora intricata*
LEC JURA=*Lecidea jurana*
LEC LIMO=*Lecidea limosa*
LEC MACR=*Lecidea macrocarpa*
LEC PANT=*Lecidea pantherina*
LEC STIG=*Lecidella stigmatea*
LEC URCE=*Lecanora urceolaria*
LEC VERN=*Lecidea vernalis*
LECIDEA =*Lecidea* species (singular)
LED DECU=*Ledum decumbens*
LED GROE=*Ledum groenlandicum*
LEP DENS=*Lepidium densiflorum*
LEP MEMB=*Lepraria membranacea*
LEP NEGL=*Lepraria neglecta*
LEP PYRO=*Leptarrhena pyrolifolia*
LES ARCT=*Lesquerella arctica*
LES RADI=*Lescuraea radicosa*
LIN BORE=*Linnaea borealis*
LLO SERO=*Lloydia serotina*
LOI PROC=*Loisleuria procumbens*
LUP ARCT=*Lupinus arcticus*
LUZ ARCU=*Luzula arcuata*
LUZ CONF=*Luzula confusa*
LUZ MULT=*Luzula multiflora*
LUZ NIVA=*Luzula nivalis*
LUZ PARV=*Luzula parviflora*
LUZ SPIC=*Luzula spicata*
LUZULA =*Luzula* species (singular)
LYC ALPI=*Lycopodium alpinum*
LYC ANNO=*Lycopodium annotinum*
LYC CLAV=*Lycopodium clavatum*
LYC SELA=*Lycopodium selago*
LYCOP SP=*Lycopodium* species (singular)
MEL APET=*Melandrium apetalum*
MER PANI=*Mertensia paniculata*
MIN ARCT=*Minuartia arctica*
MIN BIFL=*Minuartia biflora*
MIN MACR=*Minuartia macrocarpa*
MIN R EL=*Minuartia rossii elegans*
MIN ROSS=*Minuartia rossii rossii*
MIN RUBE=*Minuartia rubella*
MIN STRI=*Minuartia stricta*
MIS LICH=Miscellaneous Lichens (plural)
MOE LATE=*Moehringia lateriflora*
MOSS SPP=Miscellaneous Mosses (plural)
MYO ALPE=*Myosotis alpestris*
MYU JULA=*Myurella julacea*
NEP ARCT=*Nephroma arcticum*
NEP EXPA=*Nephroma expallidum*
OCH ANDR=*Ochrolechia androgyna*
OCH GEMI=*Ochrolechia geminipara*
OCH INAE=*Ochrolechia inaequatula*
OCH ULIG=*Ochrolechia uliginosa*
OCHRO SP=*Ochrolechia* species (singular
OLIGOTRI=*Oligotrichum* species (singula
OMP DECU=*Omphalodiscus decussatus*
OMP KRAS=*Omphalodiscus krascheninnik*
OMP VIRG=*Omphalodiscus virginis*
ONC VIRE=*Oncophorus virens*
ORT CRYS=*Orthothecium cryseum*
ORT STRI=*Orthothecium strictum*
ORTHOTRI=*Orthothrichum* species Singula
OTHR VAS=Unidentified Vascular Plant
OXY DEFL=*Oxytropis deflexa*
OXY DIGY=*Oxyria digyna*
OXY JORD=*Oxytropis jordalii*
OXY MAYD=*Oxytropis maydelliana*
OXY NIGR=*Oxytropis nigrescens*
OXY SHEL=*Oxytropis sheldonensis*
OXYTR SP=*Oxytropis* species (singular)
PAL SQUA=*Paludella squarrosa*
PAN PEZI=*Pannaria pezizoides*
PAN RUBI=*Pannaria rubiginosa*
PAP KEEL=*Papaver keelei*
PAP RADI=*Papaver radicatum*
PAPAV SP=*Papaver* species (singular)
PAR AMBI=*Parmeliopsis ambigua*
PAR CENT=*Parmelia centrfuga*
PAR FIMB=*Parnassia fimbriata*
PAR HYPE=*Parmeliopsis hyperota*
PAR KOTZ=*Parnassia kotzbuei*
PAR NUDI=*Parrya nudicaulis*
PAR PALU=*Parnassia palustris*
PAR SEPA=*Parmelia separata*
PAR SEPT=*Parmelia septentrionalis*
PARME SP=*Parmelia* species (singular)
PARNA SP=*Parnassia* species (singular
PED ARCT=*Pedicularis arctica*
PED CAPI=*Pedicularis capitata*
PED LABR=*Pedicularis labradorica*
PED LANA=*Pedicularis lanata*
PED SUDE=*Pedicularis sudetica*
PEDIC SP=*Pedicularis* species (singular
PEL APHT=*Peltigera aphthosa*
PEL CANI=*Peltigera canina*
PEL MALA=*Peltigera malacea*

Alphabetical Listing Continued

PEL POLY=*Peltigera polydactyla*
PEL PULV=*Peltigera pulverulenta*
PEL RUFE=*Peltigera rufescens*
PEL SPUR=*Pletigera spuria*
PEL VENO=*Peltogera venosa*
PELT SPP=*Peltigera* species (plural)
PELTI SP=*Peltigera* species (singular)
PER OACT=*Pertusaria dactylina*
PET FRIG=*Petasites frigidus*
PET HYPE=*Petasites hyperboreus*
PET PALM=*Petasites palmatus*
PHI FONT=*Philonotis fontana*
PHI TOME=*Philonotis tomentella*
PHL COMM=*Phleum commutatum*
PHY CAES=*Physcia caesia*
PHY EMPT=*Phyllodoce empetriformis*
PIC GLAU=*Picea glauca*
PIN VULG=*Pinguicula vulgaris*
PLA CUSP=*Plagiomnium cuspidatum*
PLA ELLI=*Plagiomnium ellipticum*
PLA JUNG=*Platydictya jugermannioides*
PLA MEOI=*Plagiomnium medium*
PLE SCHR=*Pleurozium schreberi*
POA ALPG=*Poa alpigena*
POA ALPN=*Poa alpina*
POA ARCT=*Poa arctica*
POA GLAU=*Poa glauca*
POA PAUC=*Poa pauciflora*
POA PORS=*Poa porsildii*
POA PRAT=*Poa pratensis*
POA SP =*Poa* species (singular)
POG ALPI=*Pogonatum alpinum*
POG DENT=*Pogonatum dentatum*
POG URNI=*Pogonatum urnigerum*
POH CRUO=*Pohlia cruda*
POH NUTA=*Pohlia nutans*
PCHLIA =*Pohlia* species (singular)
POL ACUT=*Polemonium acutiflorum*
POL BIST=*Polygonum bistorta*
POL BORE=*Polemonium borealis*
POL COMM=*Polytrichum commune*
POL GELA=*Polyblastia gelatinosa*
POL GOTH=*Polyblastia gothica*
POL HYPE=*Polytrichum hyperboreum*
POL JUNI=*Polytrichum juniperinum*
POL PILI=*Polytrichum piliferum*
POL SENO=*Polyblastia sendtneri*
POL STRI=*Polytrichum strictum*
POL THEL=*Polyblastia theleodes*
POL VIVI=*Polygonum viviparum*

POLY SPP=*Polytrichum* species (plural)
POLYT SP=*Polytrichum* species (singular)
POP BALS=*Populus balsamifera*
POP TREM=*Populus tremuloides*
POT BIFL=*Potentilla biflora*
POT OIVE=*Potentilla diversifolia*
POT ELEG=*Potentilla elegans*
POT FRUT=*Potentilla fruticosa*
POT HYPA=*Potentilla hyparctica*
POT NIVE=*Potentilla nivea*
POT NORV=*Potentilla norvegica*
POT PALU=*Potentilla palustris*
POT RUBR=*Potentilla rubricaulis*
POT UNIF=*Potentilla uniflora*
POT VAHL=*Potentilla vahliana*
PRI EGAL=*Primula egalisensis*
PSO HYPN=*Psoroma hypnorum*
PTI CRIS=*Ptilium crista-castrensis*
PYR ASAR=*Pyrola asarifolia*
PYR GRAN=*Pyrola grandiflora*
PYR MINO=*Pyrola minor*
PYR SECU=*Pyrola secunda*
PYROL SP=*Pyrola* species (singular)
RAN ESCH=*Ranunculus eschscholtzii*
RAN HYPE=*Ranunculus hyperboreus*
RAN NIVA=*Ranunculus nivalis*
RAN PYGM=*Ranunculus pygmaeus*
RAN SULP=*Ranunculus sulphureus*
RANUN SP=*Ranunculus* species (singular)
RHA CANE=*Rhacomitrium canescens*
RHA LANU=*Rhacomitrium lanuginosum*
RHI CHIO=*Rhizocarpon chioneum*
RHI EUPE=*Rhizocarpon eupetraeoides*
RHI GEOG=*Rhizocarpon geographicum*
RHI INAR=*Rhizocarpon inarense*
RHI PSEU=*Rhizomnium pseudopunctatum*
RHI PUNC=*Rhizomnium punctatum*
RHI RIPA=*Rhizocarpon riparium*
RHI UMBI=*Rhizocarpon umbilicatum*
RHIZO SP=*Rhizocarpon* species (singular)
RHIZOMNI=*Rhizomnium* species (singular)
RHO INTE=*Rhodiola integrifolia*
RHO LAPP=*Rhododendron lapponicum*
RHY RUGO=*Rhytidium rugosum*
RIB TRIS=*Ribes triste*
RIN ROSI=*Rinodina roscida*
RIN TURF=*Rinodina turfacea*
ROS ACIC=*Rosa acicularis*
RUB ACAU=*Rubus acaulis*
RUB CHAM=*Rubus chamaemorus*
RUM ARCT=*Rumex arcticus*

RUM OCCI=*Rumex occidentalis*
SAG INTE=*Sagina intermedia*
SAG LINN=*Sagina linnaea*
SAGINA =*Sagina* species (singular)
SAL A XP=*Salix arctica x polaris*
SAL ALAX=*Salix alaxensis*
SAL ARBU=*Salix arbusculoides*
SAL ARPH=*Salix arctophila*
SAL ARCT=*Salix arctica*
SAL BARC=*Salix barclayi*
SAL BARR=*Salix barrattiana*
SAL BRAC=*Salix brachycarpa*
SAL COMM=*Salix commutata*
SAL DOOG=*Salix dodgeana*
SAL GLAU=*Salix glauca*
SAL LANA=*Salix lanata*
SAL MYRT=*Salix myrtillifolia*
SAL PLAN=*Salix planifolia*
SAL POLA=*Salix polaris*
SAL RETI=*Salix reticulata*
SAL SPP =*Salix* species (plural)
SALIX SP=*Salix* species (singular)
SAU ANGU=*Saussurea angustifolia*
SAX AIZO=*Saxifraga aizoides*
SAX CERN=*Saxifraga cernua*
SAX OAVU=*Saxifraga davurica*
SAX FLAG=*Saxifraga flagellaris*
SAX FOLI=*Saxifraga foliosa*
SAX HIER=*Saxifraga hieracifolia*
SAX HIRC=*Saxifraga hirculus*
SAX LICH=Saxicolous Lichens
SAX OPPO=*Saxifraga oppositifolia*
SAX PUNC=*Saxifraga punctata*
SAX RAOI=*Saxifraga radiata*
SAX REFL=*Saxifraga reflexa*
SAX RIVU=*Saxifraga rivularis*
SAX SERP=*Saxifraga serphyllifoli*
SAX TRIC=*Saxifraga tricuspidata*
SCI CAES=*Scirpus caespitosus*
SCHISTID=*Schistidium* species (si
SEL SELA=*Selaginella selaginoides*
SEN ATRO=*Senecio atropurpureus*
SEN CYMB=*Senecio cymbalaria*
SEN KJEL=*Senecio kjellmanii*
SEN LUGE=*Senecio lugens*
SEN TRIA=*Senecio triangularis*
SEN YUKO=*Senecio yukonensis*
SENECIO =*Senecio* species (singular
SHE CANA=*Shepherdia canadensis*
SIB PROC=*Sibbaldia procumbens*
SIL ACAU=*Silene acaulis*

Alphabetical Listing Continued

SME BORE=*Smelowskia borealis*
SOIL LIC=Soil Lichens
SOL BISP=*Solarina bispora*
SOL CROC=*Solarina crocea*
SOL MULT=*Solidago multiradiata*
SOL SACC=*Solarina saccata*
SOLARINA=*Solarina* species (singular)
SPH GLOB=*Sphaerophorous globosus*
SPHAGNUM=*Sphagnum* species (sing.& plural)
SPI BEAU=*Spiraea beauverdiana*
SPO TEST=*Sporastatia testudinea*
STE ALPI=*Stereocaulon alpinum*
STE COND=*Stereocaulon condensatum*
STE DACT=*Stereocaulon dactylophyllum*
STE EDWA=*Stellaria edwardsii*
STE GLAR=*Stereocaulon glareosum*
STE LAET=*Stellaria laeta*
STE LONG=*Stellaria longipes*
STE MONA=*Stellaria monantha*
STE PASC=*Stereocaulon paschale*
STE RIVU=*Stereocaulon rivulorum*
STE SAXA=*Stereocaulon saxatile*
STE TOME=*Stereocaulon tomentosum*
STELL SP=*Stellaria* species (singular)
STER SPP=*Stereocaulon* species (plural)
STERE SP=*Stereocaulon* species (singular)
TAR ALAS=*Taraxacum alaskanum*
TAR MAUR=*Taraxacum maurolepium*
TAR OFFI=*Taraxacum officinale*
TARAX SP=*Taraxacum* species (singular)
TER ALGA=Terrestrial Algae
TET MNIO=*Tetraplodon mnioides*
TET PARA=*Tetraplodon paradoxus*
THA ALPI=*Thalictrum alpinum*
THA SUBU=*Thamnolia subuliformis*
THA VERM=*Thamnolia vermicularis*
THE AENE=*Thelidium aeneovinosum*
THL ARVE=*Thlaspi arvense*
TOF COCC=*Tofieldia coccinea*
TOF PUSI=*Tofieldia pusilla*
TOM NITE=*Tomenthypnum nitens*
TOMENTHY=*Tomenthypnum* species
TON LOBU=*Toninia lobulata*
TON TRIS=*Toninia tristis*
TOR ARCT=*Tortella arctica*
TOR FRAG=*Tortella fragilis*
TOR INCL=*Tortella inclinata*
TOR LATI=*Tortula latifolia*
TOR MUCR=*Tortula mucronifolia*
TOR NORV=*Tortula norvegica*
TOR RIGE=*Tortella rigens*
TOR RURA=*Tortula ruralis*
TOR TORT=*Tortella tortuosa*
TRI ARCT=*Trichostomum arcticum*
TRI CRIS=*Trichostomum crispulum*
TRI MARI=*Triglochim maritimum*
TRI PALU=*Triglochin palustris*
TRS SPIC=*Trisetum spicatum*
TRT AEST=*Triticum aestivum*
UMB H RA=*Umbilicaria hyperborea radiculata*
UMB HYPE=*Umbilicaria hyperborea*
UMB PROB=*Umbilicaria probascidea*
UMB TORR=*Umbilicaria torrefacta*
UMBIL SP=*Umbilicaria* species (singular)
VAC ULIG=*Vaccinium uliginosum*
VAC VITI=*Vaccinium vitis-idaea*
VAL CAPI=*Valeriana capitata*
VER AETH=*Verrucaria aethiobola*
VER ESCH=*Veratrum eschscholtzii*
VER MURA=*Verrucaria muralis*
VER WORM=*Veronica wormskjoldii*
VIO EPIP=*Viola epipsila*
VIOLA SP=*Viola* species (singular)
WEI CONT=*Weisia controversa*
WOO GLAB=*Woodsia glabella*
ZYG ELEG=*Zygadenus elegans*

A.1 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.)

In Carex membranacea-Sphagnum Species Tundra (n=2)

SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
CAR LUGE	0 650	1	0	ERI ANGU	3 845	2	2	ERI CALL	0 040	1	0
ERI VAGI	-6 685	2	2	TER ALGA	8 400	1	0	POL COMM	0.0	1	1
POL JUNI	0 010	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-0 600	0	2	CAR MEMB	-25 510	0	2	AND POLI	-2 700	0	2
LED DECU	-0 600	0	2	LEO GRDE	-0 010	0	2	VAC ULIG	-0 010	0	2
VAC VITI	-0 010	0	2	RUB CHAM	-0 010	0	2	PED LABR	-0 010	0	2
CET CUCU	-2 250	0	2	CLA ARBU	-0.010	0	2	CLA RANG	-2 140	0	2
CLA GONE	-0 040	0	2	CLA SUBU	-0.010	0	2	CLA UNCI	-0 010	0	2
ICM ERIC	-0 010	0	2	RHI INAR	-0 010	0	2	OCH GEMI	-0 010	0	2
HEPATICS	-0 010	0	2	MOSS SPP	-2 700	0	2	POLYT SP	-0 140	0	2
CAL SIRA	-0 010	0	2	DITRICHU	-0 010	0	2	POL COMM	-0 010	0	1
SPHAGNUM	-22 000	0	2								

B.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Miscellaneous Mosses-Carex Species Tundra (n=7)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR.	SPECIES	COV DIF	DISTB	CONTR
MER PANI	0 010	1	0	CER BEER	0 205	2	1	MIN BIFL	0 007	3	0
SAG INIE	0 520	2	0	SAO LINN	0 010	1	0	STE LAET	0 010	1	0
MOE LATE	0 640	1	0	ACH LANU	0 010	1	0	ANT MONO	-0 065	2	2
ART ARCT	2 770	6	5	ART TILE	2.050	2	0	ERI HUMI	0 040	1	0
PET FRIG	-0 240	1	1	PET HYPE	0 067	3	0	SENEC SP	0 0	1	0
SEN LUGE	0 316	5	0	SEN TRIA	0.010	2	0	TARAX SP	0 040	1	0
TAR ALAS	0 010	1	0	RHO INTE	-0 066	5	3	ARA LYRA	0.325	2	0
CAR UMBE	0 010	1	0	BRA CAMP	0 010	1	0	DRA CRAS	0.010	1	0
DRA LONG	0 010	1	0	CAR A AO	0 010	1	0	CAR POOD	-4 722	4	4
CAR VAGI	0.010	1	0	EMP NIGR	0.0	1	1	EQU ARVE	3.623	3	1
GEN GLAU	-0 140	1	1	ALO ALPI	0 010	2	0	POA PRAT	14.500	1	0
CAL CANA	0 010	1	0	DES CAES	3 248	5	0	POA ARCT	3.040	1	0
TRS SPIC	6 758	5	0	LUZ ARCU	-0 180	1	1	LUZ PARV	-0.146	5	1
LUZ SPIC	0 010	2	0	LYC SELA	-0 010	1	1	EPI ANAG	4.530	1	0
EPI ANGU	0 970	5	0	EPI LATI	1.723	3	0	BOT LUNA	0.010	1	0
POL ACUT	-0 060	2	2	POL VIVI	-0 240	1	1	RUM ARCT	0.010	1	0
PYROL SP	0 010	1	0	ACO DELP	0 010	1	0	ANE NARC	-0 070	2	2
ANE PARV	0 140	1	0	RAN ESCH	0 0	1	0	SIB PROC	0.240	7	3
SAL ALAX	0 010	4	0	SAL ARCT	0 040	1	0	SAL LANA	0 010	1	0
SAL PLAN	-0 240	5	3	SAL POLA	-0.565	2	2	SAL RETI	-1.545	2	2
CHR TETR	0 040	1	0	PAR KOTZ	0 170	2	1	CASTI SP	0.010	1	0
LAG STEL	0 010	1	0	PED SUDE	-0 140	2	2	VER WORM	1 560	1	0
MIS LICH	6 850	2	0	CET NIVA	0 0	1	0	CET RICH	-0 140	1	1
CLADO SP	0 0	1	0	CLA CARI	0.353	3	0	CLA CHLO	0.0	1	0
CLA FIMB	0 0	1	0	CLA G GR	0.010	1	0	CLA PLEU	0.0	1	0
DAC ARCT	0 010	1	0	DAC BERI	0 010	1	0	PAN PEZI	0.010	1	0
PEL APHT	-0 845	2	2	PEL CANI	0 467	3	0	PEL MAIA	0.0	1	0
PEL RUFE	0 440	3	0	PEL SPUR	0 0	1	0	PSO HYPN	0 0	1	0
SOL CROC	0 580	2	2	STE ALPI	0 010	1	0	STE GLAR	0 010	1	0
STE SAXA	0 070	2	0	STE TOME	2.580	2	0	TON LOBU	0 010	1	0
SOIL LIC	0 190	1	0	STERE SP	0 0	1	0	HEPATICS	0 013	3	0
MOSS SPP	-32 889	7	7	POLYT SP	0 090	1	0	AUL PALU	0 010	1	1
BRYUM SP	0 0	2	0	BRY PSEU	0 010	1	0	CAT NIGR	0 0	1	0
CER PURP	0 0	2	0	DESMATAO	0 0	1	0	DES LATI	0.0	1	0
DRE UNCI	0 0	3	0	DNC VIRE	0 0	1	0	PLE SCHR	0.0	1	1
POG ALPI	0 0	1	0	POG URNI	0 0	1	0	POHLIA	0.0	1	0
POL HYPE	0 0	1	0	POL JUNI	0 0	2	0	POL PILI	0.0	1	0
RHA CANE	0 0	3	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF	DISTB	CONTR	SPECIES	COV.DIF.	DISTB.	CONTR.
BET GLAN	-0 010	0	1	MYO ALPE	-0.010	0	2	MIN BIFL	-0 040	0	1
STELL SP	-0 010	0	1	ANT MONO	-0.340	0	2	PET FRIG	-0 070	0	4
SEN ATRO	-0 065	0	2	SEN TRIA	-0.140	0	1	SEN YUKO	-0 050	0	2
RHO INTE	-0 600	0	1	DRA ALBE	-0 010	0	1	CAREX SP	-0 365	0	2
CAR A ST	-9 007	0	3	CAR PODD	-22 000	0	1	ERI ANGU	-0 010	0	2
EQU SCIR	-0 010	0	1	CAS TETR	-3.640	0	3	KAL P MI	-0.250	0	1
LED GRDE	-0 010	0	2	VAC ULIG	-0 010	0	1	VAC VITI	-0 750	0	1
COR PAUC	-0 010	0	1	GEN GLAU	-0 095	0	4	ARC LATI	-4.355	0	2
DES CAES	-2 020	0	1	SAL COMM	-2 020	0	1	FES ALTA	-4.530	0	1
POA PORS	-0 010	0	1	LUZ ARCU	-0 090	0	2	LLO SERO	-0 010	0	1
LYC ALPI	-0 020	0	3	LYC SELA	-0 010	0	2	POL ACUT	-0.487	0	3
POL VIVI	-0 040	0	2	RUM ARCT	-0 390	0	1	CLA TUBE	-0.130	0	2
PYROL SP	-0 010	0	1	ANE NARC	0 470	0	3	ANE PARV	-0.010	0	1
ANE RICH	0 540	0	1	RAN ESCH	-0 010	0	1	RAN SULP	-0 250	0	1
RUB ACAU	-0 140	0	1	SAL PLAN	-4 800	0	1	SAL POLA	-1 987	0	4
CHR TETR	-0 090	0	1	SAX HIER	-0 040	0	1	LAG STEL	-0.225	0	2
PED SUDE	-0 010	0	3	VIO EPIP	0.010	0	1	CET ISLA	-0.946	0	5
CET RICH	0 065	0	4	CLA ARBU	-0 440	0	1	CLA RANG	-2.992	0	4
CLA STEL	-10 910	0	1	CLA BELL	0 0	0	2	CLA CARN	0.0	0	1
CLA COCC	-0 002	0	6	CLA CORN	-0 010	0	1	CLA CRIS	-2.020	0	1
CLA DEFO	0 0	0	2	CLA ECMO	-0.617	0	3	CLA FIMB	-0 010	0	1
CLA GONE	0 0	0	3	CLA G GI	0 0	0	1	CLA G GR	-0 005	0	2
CLA META	0 0	0	1	CLAD SPP	-0 382	0	5	DAC ARCT	-0.123	0	3
DAC BERI	-0 700	0	1	LEC GRAN	-0 250	0	1	NEP EXPA	-0 040	0	1
PEL APHT	-0 480	0	3	PEL MALA	-0 010	0	1	SOL CROC	-0 090	0	2
STE PASC	-1 300	0	4	UMB HYPE	-0 010	0	1	LEP NEGL	-1.000	0	1
HEPATICS	-0 003	0	3	AULAC SP	0 0	0	1	AUL PALU	0.0	0	1
BRACH SP	0 0	0	1	BRYUM SP	0 0	0	1	DICRANUM	0.0	0	3
DRE UNCI	0 0	0	3	HYL SPLE	0 0	0	5	PLE SCHR	0 0	0	2
POG ALPI	0 0	0	1	POL COMM	0 0	0	4	POL JUNI	0 0	0	1
POL STRI	0 0	0	1	RHA CANL	0 0	0	2	SPHAGNUM	0 0	0	1
TOMENTHY	0 0	0	1	TOM NITE	0 0	0	2	CYRTOMNI	0 0	0	1
PLA CUSP	0 0	0	1	RHI PSEU	0 0	0	1				

B.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Disb.) and Their Controls (Contr.) In Miscellaneous Mosses-<u>Carex</u> Species Tundra (n=6)

SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.
BET GLAN	0.0	1	1	ANIEN SP	0.010	1	0	ANT MONO	0.257	3	3
ART ARCT	-0.620	4	3	PET FRIG	0.010	1	0	PET HYPE	0.440	1	0
SEN ATRO	0.300	1	1	SEN LUGE	0.010	1	0	SEN YUKO	0.0	1	1
TARAX SP	0.040	1	0	RHO INTE	-1.060	2	2	DRA LONG	0.010	1	0
CAREX SP	0.010	1	0	CAR BRUN	0.010	1	0	CAR MICH	12.500	1	0
CAR PODO	2.610	2	2	ERI ANGU	10.255	2	0	ERI VAGI	0.010	1	0
EMP NIGR	0.0	1	1	EQU ARVE	0.250	1	0	EQU SCIR	0.010	1	0
CAS TETR	-10.890	1	1	LEO DECU	0.010	1	0	VAC ULIG	0.0	1	1
VAC VITI	-0.740	1	1	GEN GLAU	0.055	2	2	ARC LATI	7.475	2	1
DES CAES	0.140	1	0	FES ALTA	-4.390	1	1	HIE ALPI	0.010	1	0
POA ALPN	15.000	1	0	POA ARCT	0.040	1	0	TRS SPIC	3.120	2	1
LUZULA	0.010	1	0	LUZ ARCU	10.810	1	1	LUZ PARV	0.010	2	0
LYC ALPI	-0.030	1	1	EPI ANGU	0.850	1	0	EPI LATI	0.010	1	0
PUL ACUT	0.005	2	1	OXY DIGY	0.010	1	0	RUM ARCT	0.040	1	0
PYR ASAR	0.010	1	0	RAN ESCH	0.0	1	1	RAN NIVA	0.005	2	1
PUT PALU	0.010	1	0	RUB ACAU	0.010	1	0	SIB PROC	1.310	2	1
SAL ALAX	0.600	1	0	SAL ARCT	0.010	1	0	SAL GLAU	0.010	1	0
SAL PLAN	0.520	3	2	SAL PULA	-0.495	2	2	SAL RETI	0.010	2	0
PAR KOTZ	0.090	1	0	SAX FOLI	0.075	2	0	SAX HIER	0.140	1	0
PED SUDE	0.0	1	1	MIS LICH	43.000	1	0	BAE RUFU	0.0	1	0
CET CUCU	0.010	1	0	CET DELI	0.010	1	0	CET ISLA	1.267	3	3
CET NIVA	0.275	2	0	CET RICH	1.367	3	3	CLA STEL	-10.620	1	1
CLA CARN	0.250	1	0	CLA COCC	0.437	3	3	CLA CORN	0.440	1	0
CLA GONE	0.755	2	0	CLA MACA	0.010	1	0	CLA UNCI	0.390	1	0
DAC ARCT	0.050	1	1	DAC BERI	-0.510	1	1	PAN PEZI	0.140	1	0
PEL APHT	1.075	2	2	PEL CANI	2.750	1	0	PEL MALA	0.650	1	0
PEL POLY	1.000	1	0	PEL RUFE	0.010	1	0	PSO HYPN	0.040	1	0
SOL CROC	1.705	2	2	STE ALPI	2.480	1	0	STE GIAR	0.010	1	0
STE SAXA	2.480	1	0	STE TOME	3.970	1	0	TON LOBU	0.010	1	0
CRUSTOSE	0.540	1	0	SOIL LIC	3.610	1	0	CET SUBA	0.0	1	0
HEPATICS	0.0	2	0	MOSS SPP	-17.790	5	5	POLYT SP	40.000	1	0
AUL PALU	0.0	2	0	BRYUM SP	0.0	2	0	CAL STRA	0.0	1	0
CAM STEL	0.0	1	0	DIC PALL	0.010	1	0	ORE UNCI	0.0	1	1
HYL SPLE	0.0	1	1	JUGERMAN	0.0	1	0	POL COMM	0.0	1	0
POL HYPE	0.0	3	0	POL JUNI	0.0	1	1	POL STRI	0.0	1	0
RHA CANE	0.010	1	1	TOM NITE	0.0	1	0	PAL SQUA	0.0	1	0

----- - IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN BIFL	-0.040	0	1	ANT MONO	-0.010	0	1	PLT FRIG	0.130	0	2
SEN ATRO	-0.090	0	1	SEN YUKO	-0.050	0	2	RHO INTE	0.090	0	1
CAREX SP	-0.140	0	1	CAR A ST	-18.003	0	3	CAR MICH	-0.010	0	1
CAR PODO	0.010	0	1	CAS TETR	0.010	0	2	KAL P MI	-0.250	0	1
LEO GROE	0.010	0	3	GEN GLAU	-0.080	0	3	SAL COMM	-2.020	0	1
LUZ ARCU	-0.050	0	2	LYC ALPI	-0.010	0	1	LYC SELA	0.010	0	2
POL ACUT	-0.010	0	1	POL VIVI	-0.040	0	1	PYROL SP	-0.010	0	1
ANE NARC	-0.470	0	3	ANE PARV	-3.040	0	1	GEU RUSS	-3.040	0	1
SIB PROC	-0.090	0	1	SAL PULA	-0.100	0	2	PEDIC SP	-0.010	0	1
PED SUDE	-0.010	0	2	MIS LICH	-31.000	0	1	CET ISLA	-1.950	0	2
CET RICH	-0.073	0	3	CLA ARBU	-0.440	0	1	CLA RANG	-3.980	0	4
CLA BELL	0.0	0	3	CLA CARN	0.0	0	2	CLA COCC	0.0	0	2
CLA CRIS	-2.020	0	1	CLA DEFU	0.0	0	1	CLA ECMO	-0.525	0	2
CLA GONE	0.0	0	2	CLA G DI	0.0	0	1	CLA G GR	0.007	0	3
CLA META	0.0	0	1	CLAD SPP	-0.534	0	5	DAC ARCT	-0.115	0	2
LEC GRAN	-0.250	0	1	NEP EXPA	-0.040	0	1	PEL APHT	-1.260	0	1
SOL CROC	0.900	0	1	STE PASC	-1.703	0	3	UMB HYPE	-0.010	0	1
LEP NIGI	1.000	0	1	HEPATICS	-0.003	0	3	MOSS SPP	-31.000	0	1
DICRANUM	0.0	0	2	DRE UNCI	0.0	0	1	HYL SPLE	0.0	0	2
PLE SCHR	0.0	0	2	POL COMM	0.0	0	3	POL JUNI	0.0	0	1
RHA CANE	0.0	0	1	SPHAGNUM	0.0	0	2				

B.3 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.) In Miscellaneous Mosses-<u>Carex</u> Species Tundra (n=8)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF.	DISTB	CONTR
BET GLAN	0.0	1	1	MYO ALPE	0.0	1	1	ANIEN SP	0.140	1	0
ANI MONO	0.015	4	3	ART ARCT	-0.787	7	6	PET FRIG	-0.024	5	5
PET HYPE	0.010	1	0	SEN ATRO	0.0	1	1	SEN YUKO	0.0	1	1
TAR ALAS	0.030	1	1	RHO INTE	-0.122	5	4	CRUCIFER	0.090	1	0
DRA ALBE	0.0	1	1	CAREX SP	0.325	2	1	CAR A ST	-8.783	3	3
CAR PODO	-5.992	5	5	ERI ANGU	0.0	1	1	EMP NIGR	0.0	1	1
EQU ARVE	0.005	2	1	EQU SCIR	0.0	1	1	CAS TETR	-5.412	4	4
VAC ULIG	0.030	1	1	VAC VITI	-0.500	1	1	GEN GLAU	-0.078	6	5
GRAMINEA	11.000	1	0	DES CAES	-2.370	3	2	SAL COMM	0.0	1	1
FES ALTA	-4.490	1	1	POA PORS	0.0	1	1	JUN BIGL	0.010	1	0
JUN CAST	0.010	1	0	JUN ALBE	0.010	1	0	LUZ ARCU	-0.670	5	3
LUZ PARV	-1.450	2	1	EPILO SP	0.025	2	0	LLO SERO	0.0	1	1
LYC ALPI	-0.010	3	3	LYC SELA	0.013	3	2	EPI ANGU	0.010	2	0
POL ACUT	-0.280	6	6	POL VIVI	0.040	4	4	RUM ARCT	0.250	1	0
CLA TUBE	0.0	1	1	ANE NARC	-0.293	4	4	ANE PARV	0.0	1	1
ANE RICH	-0.530	1	1	RAN NIVA	0.227	3	0	RAN SULP	0.0	1	1
SIB PROC	0.003	3	2	SPI BEAU	0.010	1	0	SAL ARCT	0.290	1	0
SAL PLAN	-1.644	5	4	SAL POLA	0.003	4	3	SAL A XP	0.290	1	0
SAL RETI	0.005	2	1	CHR TETR	0.090	1	0	PAR KOTZ	0.0	1	1
SAX FOLI	-0.030	2	2	SAX HIER	0.005	2	1	SAX PUNC	0.090	1	0
SAX REFL	0.010	1	0	SAX RIVU	0.010	1	0	LAG STEL	-0.120	2	2
PED SUDE	-0.034	5	4	VER WORM	0.010	1	0	TER ALGA	0.030	1	1
MIS LICH	1.075	2	0	BAE RUFU	0.005	2	0	CET ISLA	-0.766	5	5
CET RICH	0.012	4	4	CLA ARBU	0.0	1	0	CLA RANG	-2.200	3	3
CLA STEL	-9.550	1	1	CLA CARN	0.005	3	0	CLA COCC	0.007	6	6
CLA DEFO	0.0	3	2	CLA ECMO	0.0	2	2	CLA GONE	0.002	5	3
CLA G GR	0.0	1	0	CLA MACA	2.290	1	0	CLA SUBU	2.290	1	0
CLAD SPP	-0.125	4	4	DAC ARCT	0.010	4	3	LEC GRAN	-0.250	1	1
NEP ARCT	0.0	1	1	PEL APHT	-0.248	5	4	PEL PULV	0.0	1	1
PEL VENO	0.750	1	0	SOL CRUC	0.0	2	2	STE PASC	-0.967	3	3
STE TOME	0.225	2	0	BUE SCAB	0.0	1	0	HEPATICS	0.0	2	1
MOSS SPP	-16.857	8	8	AUL PALU	0.0	4	4	BRA GROE	0.0	1	0
BRYUM SP	0.0	1	1	CRA COMM	0.0	1	0	DICRANUM	0.0	2	2
ORE REVO	0.0	2	0	ORE UNCI	0.0	2	1	HYL SPLE	0.0	3	3
PLE SCHR	0.0	3	3	POG ALPI	0.0	3	2	POHLIA	0.0	1	0
POL COMM	0.0	3	3	POL HYPE	0.0	1	0	POL JUNI	0.0	4	1
POL STRI	0.0	2	1	RHA CANE	0.0	4	2	SPHAGNUM	0.010	1	1
PHI FONT	0.0	1	0	TOM NITE	0.0	1	1	BAR ITHY	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF.	DISTB	CONTR
MYO ALPE	0.010	0	1	CER BEER	-0.140	0	1	MIN BIFE	-0.040	0	1
STELL SP	-0.010	0	1	PET FRIG	-0.010	0	1	PET HYPE	-0.290	0	1
SEN ATRO	-0.050	0	2	SEN TRIA	-0.075	0	2	RHO INTE	-0.090	0	1
CAREX SP	-4.190	0	1	CAR PODO	-0.050	0	2	ERI ANGU	-0.010	0	2
KAL P MI	-0.250	0	1	LEO GROE	-0.010	0	2	COR PAUC	-0.010	0	1
GEN GLAU	-0.010	0	1	ARC LATI	-5.560	0	1	LYC SELA	-0.010	0	1
POT ACUT	-0.010	0	1	RUM ARCT	-0.390	0	1	CLA TUBE	-0.010	0	1
PYROL SP	-0.010	0	1	ANE NARC	-0.010	0	1	RAN SULP	-0.540	0	1
RUB ACAU	-0.140	0	1	SAL ARCT	-7.460	0	1	SAL POLA	-0.433	0	3
SAL A XP	-0.010	0	1	SAL RETI	-0.195	0	2	CHR TETR	-0.090	0	1
LAG STEL	0.010	0	1	PED SUDE	-0.010	0	1	VIO EPIP	-0.010	0	1
CET CUCU	-0.010	0	1	CET ISLA	-0.010	0	1	CET NIVA	-0.190	0	1
CET RICH	-0.040	0	1	CLA ARBU	-1.355	0	2	CLA RANG	-4.340	0	1
CLA BELL	0.0	0	2	CLA CARN	0.0	0	1	CLA CENO	-0.010	0	1
CLA CORN	-0.010	0	1	CLA ECMO	-0.250	0	1	CLA FIMB	-0.010	0	1
CLA GONE	0.0	0	1	CLA G DI	-0.005	0	2	CLA G GR	-0.010	0	3
CLA META	0.0	0	1	CLA PLEU	-0.010	0	1	CLAD SPP	-0.290	0	1
DAC ARCT	-0.010	0	1	DAC BERI	-0.475	0	2	NEP ARCT	-0.600	0	1
NEP EXPA	-0.040	0	1	PEL MALA	-0.010	0	1	SOL CROC	-0.040	0	1
UMB HYPE	0.010	0	1	HEPATICS	-0.003	0	3	AULAC SP	0.0	0	1
BRACH SP	0.0	0	1	DICRANUM	0.0	0	2	ORE UNCI	0.0	0	2
HYL SPLE	0.0	0	2	POL JUNI	0.0	0	1	POL STRI	0.0	0	2
TOMENTHY	0.0	0	1	TOM NITE	0.0	0	1	CYRTOMNI	0.0	0	1
PLA CUSP	0.0	0	1	RHI PSEU	0.0	0	1				

B.4 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Miscellaneous Mosses-Carex Species Tundra (n=6)

SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0.0	1	1	MER PANI	0.010	1	0	CER BEER	0.030	1	1
MIN BIFL	1.000	1	0	SAG LINN	0.010	1	0	SIL ACAU	0.010	1	0
STE LAET	0.010	1	0	ANTEN SP	0.010	1	0	ANT MONO	0.207	4	3
ARN LESS	0.010	1	0	ARI ARCT	0.602	4	3	ERIGE SP	0.010	1	0
ERI HUMI	0.010	3	0	PET FRIG	-0.115	2	1	PET HYPE	3.040	1	0
SEN LUGE	0.190	1	0	SEN TRIA	-0.060	2	1	SOL MULT	0.010	1	0
TARAX SP	0.010	1	0	RHO INIE	0.247	3	2	CAR BELL	0.010	1	0
DRA LONG	0.010	2	0	DRA ALBE	0.040	1	0	CAREX SP	0.0	2	0
CAR PODO	-10.990	2	1	ERI ANGU	15.500	2	0	EQU ARVE	0.650	1	0
EQU SCIR	0.010	1	0	CAS TETR	0.010	1	0	VAC VITI	-0.740	1	1
GEN GLAU	0.010	1	0	GRAMINEA	9.000	1	0	ARC LATI	-0.110	1	1
DES CAES	0.025	2	0	FES ALTA	-2.255	2	1	POA ALPN	0.010	1	0
POA ARCT	0.340	1	0	IRS SPIC	2.497	4	0	JUN BALT	0.010	1	0
LUZ ARCU	-0.180	1	1	LUZ PARV	-0.570	1	1	LUZ SPIC	0.010	1	0
EPILO SP	0.0	1	0	LYC SELA	0.010	1	0	EPI ANAG	0.040	1	0
EPI ANGU	0.007	3	0	EPI LATI	0.008	4	0	BOT LUNA	0.010	1	0
POL ACUT	-0.635	2	2	POL VIVI	0.010	1	0	RUM ARCT	0.0	2	0
PYR SECU	0.010	1	0	ANE NARC	-0.330	2	2	ANE PARV	0.010	2	0
RAN ESCH	0.003	3	1	RAN PYGM	0.0	1	0	DRY OCTO	0.010	2	0
RUB ACAU	0.010	1	0	SIB PROC	2.337	4	2	POP BALS	0.010	1	0
SAL ALAX	1.020	3	0	SAL ARCT	0.010	1	0	SAL GLAU	0.010	1	0
SAL LANA	2.010	3	0	SAL PLAN	2.048	5	3	SAL A XP	1.410	1	0
SAL RETI	-0.045	2	1	PAR KOTZ	0.010	1	0	SAX HIER	0.010	1	0
PED SUDE	0.045	2	1	VER WORM	0.800	1	0	BASIDIOM	0.040	1	0
MIS LICH	85.500	1	0	BAE RUFU	0.0	1	0	CET ISLA	-0.143	3	2
CET NIVA	0.005	2	0	CET PINA	0.0	1	0	CLA ARBU	0.010	1	0
CLA CARI	1.310	1	0	CLA CARN	0.005	2	0	CLA GONE	0.010	1	0
CLA MACA	0.0	1	0	CLA POCI	1.310	1	0	CLA UNCI	0.010	1	0
DAC ARCT	0.010	1	0	DAC BERI	-0.345	2	1	NEP ARCT	0.0	1	0
PAN PEZI	1.013	3	0	PEL APHT	-0.322	5	4	PEL POLY	0.0	1	0
PEL RUFE	0.090	1	0	PEL VENO	0.010	1	0	SOL BISP	0.010	1	0
SOL CROC	0.405	2	1	STE ALPI	4.010	2	0	STE TOME	12.445	2	0
TON LOBO	0.0	2	0	SOIL LIC	11.000	1	0	LEC JURA	0.250	1	0
VER AETH	0.250	1	0	HEPATICS	0.0	1	0	MOSS SPP	-15.533	6	6
POLYT SP	0.290	1	0	AUL PALU	0.010	1	1	BRYUM SP	0.005	2	1
CAL SARM	0.0	1	0	CAL STRA	0.0	1	0	ORE ALVO	0.0	1	0
ORE UNCI	0.0	2	1	HYL SPLE	0.010	1	1	POG ALPI	0.0	1	0
POL COMM	0.0	1	1	POL HYPE	0.0	1	0	POL JUNI	0.0	4	0
POL PILI	0.0	2	0	RHA CANE	0.003	4	1				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB.	CONTR
MYO ALPE	-0.010	0	1	CER BEER	-0.140	0	1	MIN BIFL	-0.040	0	1
STELL SP	-0.025	0	2	ANT MONO	-0.340	0	2	ART ARCT	-1.660	0	2
PET FRIG	-0.010	0	3	PET HYPE	-0.500	0	1	SEN LUGE	-0.190	0	1
SEN YUKO	-0.090	0	1	RHO INIE	-0.927	0	3	DRA LONG	-0.010	0	1
DRA ALBE	-0.040	0	1	CAREX SP	-0.140	0	1	CAR A ST	-0.010	0	2
CAR PODO	-0.487	0	4	ERI ANGU	0.010	0	1	EMP NIGR	-0.010	0	1
CAS TETR	3.640	0	3	KAL P MI	-0.250	0	1	LED GROL	-0.010	0	1
VAC ULIG	-0.010	0	1	COR PAUC	0.010	0	1	GEN GLAU	-0.127	0	4
ARC LATI	5.560	0	1	SAL COMM	-2.020	0	2	POA PORS	13.000	0	1
LUZ ARCU	0.073	0	3	LYC ALPI	-0.020	0	3	LYC SELA	-0.010	0	3
POL ACUT	-0.057	0	3	POL VIVI	-0.110	0	3	RUM ARCT	-0.390	0	1
CLA TUDE	0.075	0	2	PYROL SP	-0.010	0	1	ANE NARC	0.658	0	4
ANE RICH	0.540	0	1	RAN NIVA	-0.190	0	1	GEU ROSS	-6.020	0	1
RUB ACAU	0.140	0	1	SIB PROC	-0.090	0	1	SAL PLAN	-4.250	0	1
SAL POLA	-2.347	0	6	SAL RETI	0.040	0	1	CHR TETR	-0.090	0	1
SAX HIER	0.590	0	1	SAX PUNC	-0.040	0	1	LAG STEL	-0.050	0	2
PED SUDE	-0.010	0	3	VIO EPIP	-0.010	0	1	MIS LICH	-0.290	0	1
CET ISLA	0.277	0	3	CET LAEV	0.0	0	1	CET RICH	-0.090	0	4
CLA ARBU	-0.440	0	1	CLA RANG	-2.543	0	3	CLA STEL	-10.910	0	1
CLA BELL	0.0	0	1	CLA COCC	-0.002	0	6	CLA CORN	-0.010	0	1
CLA CRIS	1.010	0	2	CLA DEFO	0.0	0	2	CLA ECMO	0.462	0	4
CLA FIMB	0.010	0	1	CLA GONE	0.0	0	3	CLA G OI	0.0	0	1
CLA G GR	0.0	0	1	CLA META	0.0	0	1	CLA UNCI	0.0	0	1
CLAO SPP	0.220	0	5	DAC ARCT	-0.140	0	2	DAC BERI	-2.950	0	1
LEC GRAN	-0.250	0	1	NEP EXPA	0.040	0	1	PEL APHT	-1.100	0	1
PEL MALA	0.010	0	1	SOL CROC	-0.613	0	3	STE PASC	-1.300	0	4
STE TOME	-0.090	0	1	UMB HYPE	-0.010	0	1	LEP NEGI	-1.000	0	1
HEPATICS	0.003	0	3	AULAC SP	0.0	0	1	AUL PALU	0.0	0	1
BRACH SP	0.0	0	1	BRA ERYT	0.0	0	1	BRYUM SP	0.0	0	1
DICRANUM	0.0	0	3	ORE UNCI	0.0	0	3	HYL SPLE	0.0	0	4
PLA ELLI	0.0	0	1	PLE SCHR	0.0	0	3	POG ALPI	0.0	0	2
POL COMM	0.0	0	3	POL JUNI	0.0	0	1	POL STRI	0.0	0	1
RHA CANE	0.0	0	2	TOMENTHY	0.0	0	1	TOM NITE	0.0	0	1
TOR NORV	0.0	0	1	CIN STYG	0.0	0	1	CETFOMNI	0.0	0	1
PLA CUSP	0.0	0	1	RHI PSEU	0.0	0	1				

B.5 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.)

In Miscellaneous Mosses-Carex Species Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.
BET GLAN	0.0	1	1	CER BEER	0.030	1	1	MIN BIFL	0.340	1	0
ANT MONO	0.060	2	2	ART ARCT	-0.050	2	2	ERI HUMI	0.090	1	0
PET FRIG	0.140	1	0	SEN LUGE	0.080	2	1	TAR ALAS	0.140	1	0
RHO INIE	-0.975	2	2	DRA CRAS	0.010	1	0	DRA LONG	0.130	1	1
EQU ARVE	0.140	1	0	EQU SYLV	0.010	1	0	DES CAES	1.100	1	0
IRS SPIC	1.825	2	0	EPI ANGO	0.010	1	0	EPI LATI	5.560	1	0
ANE NARC	-2.330	1	1	ANE PARV	0.010	1	0	RAN ESCH	0.010	1	0
GEU ROSS	-6.010	1	1	RUB ACAU	0.010	1	0	SIB PROC	0.140	1	0
SAL ALAX	0.010	1	0	SAL LANA	0.010	1	0	SAL PLAN	-4.210	1	1
SAL POLA	-2.520	2	2	SAL A XP	0.140	1	0	SAL RETI	-0.010	2	1
SAX HIER	-0.580	1	1	LAG STEL	-0.080	1	1	PED SUDE	0.005	2	1
DAC BERI	-2.940	1	1	PEL APHT	-0.460	1	1	PEL CANI	0.040	1	0
PEL RUFE	0.800	1	0	STE TOME	0.190	1	0	MOSS SPP	0.750	2	2
HYL SPLE	0.0	1	0	PLE SCHR	0.0	1	0	POL JUNI	0.0	1	1
RHA CANE	0.0	1	0	TOR NORV	0.0	2	1				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR
MIN BIFL	-0.040	0	1	STELL SP	-0.040	0	1	PET HYPE	-0.500	0	1
DRA ALBE	-0.040	0	1	CAR FOCO	-0.835	0	2	EMP NIGR	-0.010	0	1
CAS TETR	-10.900	0	1	KAL P MI	-0.250	0	1	LEO GROE	-0.010	0	1
VAC ULIG	-0.010	0	1	VAC VITI	-0.750	0	1	GEN GLAU	-0.140	0	1
FES ALTA	-4.530	0	1	POA PORS	-13.000	0	1	LUZ ARCU	-0.040	0	1
LYC ALPI	-0.040	0	1	LYC SELA	-0.010	0	1	POL ACUT	-0.050	0	2
POL VIVI	-0.250	0	1	CLA TUBE	-0.140	0	1	PYROL SP	-0.010	0	1
ANE NARC	-1.260	0	1	RAN NIVA	-0.190	0	1	SAX PUNC	-0.040	0	1
MIS LICH	0.290	0	1	CET ISLA	-0.240	0	2	CET LAEV	0.0	0	1
CET RICH	-0.040	0	1	CLA RANG	-6.850	0	1	CLA STEL	-10.910	0	1
CLA COCC	0.0	0	2	CLA CRIS	0.0	0	1	CLA ECMO	-0.125	0	2
CLA G OI	0.0	0	1	CLA META	0.0	0	1	CLA UNCI	0.0	0	1
CLAO SPP	-0.140	0	2	DAC BERI	-0.700	0	1	LEC GRAN	-0.250	0	1
NEP EXPA	-0.040	0	1	PEL APHT	-1.100	0	1	SOL CROC	-0.040	0	1
STE PASC	-2.900	0	1	STE TOME	-0.090	0	1	UMB HYPE	-0.010	0	1
HEPATICS	-0.005	0	2	AUL PALU	0.0	0	1	BRA ERYT	0.0	0	1
BRYUM SP	0.0	0	1	DICRANUM	0.0	0	1	ORE UNCI	0.0	0	2
HYL SPLE	0.0	0	1	PLA ELLI	0.0	0	1	PLE SCHR	0.0	0	1
POG ALPI	0.0	0	1	POL COMM	0.0	0	1	RHA CANE	0.0	0	1
CIN STYG	0.0	0	1								

C.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Hedysarum alpinum-Moss Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0.0	1	1	ARN ALPI	0.010	1	0	AST SIBI	-0.740	1	1
ERI ERIO	0.0	1	1	CAR MEMB	0.0	1	1	CAR SCIR	0.0	1	1
SHE CANA	0.030	1	1	EQU ARVE	-0.030	1	1	EQU VARI	-0.240	1	1
ARC ALPI	-0.180	1	1	GEN PROP	-0.240	1	1	AGP VIOL	0.0	1	1
CAL LAPP	0.010	1	0	TRS SPIC	0.0	1	1	HED ALPI	-34.490	1	1
OXY DEFL	0.160	1	1	ZYG ELEG	0.0	1	1	EPI LATI	0.0	1	1
POL VIVI	-0.530	1	1	ANE PARV	-0.180	1	1	DRY INIE	0.010	1	0
POP BALS	0.010	1	0	SAL ALAX	5.620	1	1	SAL RETI	-9.500	1	1
PAR PALU	0.0	1	1	MOSS SPP	-22.740	1	1	BRYUM SP	0.0	1	0
DIT FLEX	0.0	1	0								

------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR
ARN LESS	-0.010	0	1	SEN LUGE	-0.010	0	1	SOL MULT	0.010	0	1
CAR AURE	-0.010	0	1	CAR CAPI	-0.090	0	1	ERI CALL	-0.010	0	1
ARC LATI	-0.040	0	1	DES CAES	-0.010	0	1	FES ALTA	-0.010	0	1
POA ALPN	-0.010	0	1	JUN CAST	-0.010	0	1	JUN ALBE	-0.010	0	1
TOF PUSI	-0.040	0	1	EPI ANGU	-0.010	0	1	SAL LANA	-0.900	0	1
PAR KOTZ	-0.010	0	1	PEDIC SP	-0.040	0	1	FUNGI	-0.290	0	1
BASIDIOM	-0.040	0	1	HEPATICS	0.0	0	1	BRY BIMU	0.0	0	1
CAM STEL	0.0	0	1	DIS INCL	0.0	0	1	ORE SINU	0.0	0	1
ORE UNCI	0.0	0	1	HYP LIND	0.0	0	1	TOM NITE	0.0	0	1

C.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In Hedysarum alpinum-Moss Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MER PANI	0.010	1	0	CER BEER	0.010	1	0	MIN R EL	0.010	1	0
SIL ACAU	0.010	1	0	ARN ALPI	0.010	1	0	ARN LESS	0.0	1	1
ERI TRIMI	0.290	1	0	PET FRIG	0.010	1	0	SEN LUGE	0.0	2	2
SEN CYMB	0.010	1	0	SOL MULT	0.0	1	1	TAR ALAS	0.010	1	0
RHO INIE	0.010	1	0	DRA ALBE	0.010	1	0	CAR AURE	0.030	1	1
CAR CAPI	0.050	1	1	CAR MEMB	0.0	1	1	EQU ARVE	2.440	1	1
EQU VARI	0.060	1	1	ARC ALPI	1.900	1	1	GEN PROS	0.090	1	0
GEN PROP	-0.160	1	1	HIE ODOR	0.440	1	0	TRS SPIC	0.0	1	1
JUN CAST	2.470	1	1	JUN ALBE	0.0	1	1	HED ALPI	-32.360	1	1
OXY DEFL	1.270	1	1	LLO SERO	0.010	1	0	TOF PUSI	-0.030	1	1
EPI ANGU	0.0	1	1	EPI LATI	0.030	1	1	OXY DIGY	0.010	1	0
POL VIVI	0.200	1	1	ANE PARV	2.960	1	1	DRY SYLV	1.075	2	0
GEU ROSS	0.010	1	0	POT FRUT	0.010	1	0	RUB ACAU	0.010	1	0
SAL ALAX	-3.780	1	1	SAL GLAU	0.010	1	0	SAL LANA	-0.760	1	1
SAL RETI	1.120	1	1	PAR KOTZ	0.015	2	2	VER WORM	0.010	1	0
MOSS SPP	-12.245	2	2								

------- IN CONTROLS BUT NOT IN DISTURBANCES ---

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR
BET GLAN	-0.010	0	2	ARN LESS	0.010	0	1	AST SIBI	0.750	0	2
ERI ERIO	0.010	0	2	SOL MULT	-0.010	0	1	CAR AURE	-0.010	0	1
CAR CAPI	-0.090	0	1	CAR MEMB	-0.010	0	1	CAR SCIR	-0.010	0	2
ERI CALL	0.010	0	2	SHE CANA	0.040	0	2	EQU ARVE	-0.040	0	1
EQU VARI	0.250	0	1	ARC ALPI	0.190	0	1	GEN PROP	-0.250	0	1
AGP VIOL	0.010	0	2	ARC LATI	-0.040	0	2	DES CAES	-0.010	0	2
FES ALTA	0.010	0	2	POA ALPN	-0.010	0	2	TRS SPIC	-0.010	0	1
JUN CAST	0.010	0	1	JUN ALBE	-0.010	0	1	HED ALPI	-34.500	0	1
OXY DEFL	0.090	0	1	TOF PUSI	-0.040	0	1	ZYG ELEG	-0.010	0	2
EPI ANGU	0.010	0	1	EPI LATI	-0.010	0	1	POL VIVI	-0.540	0	1
ANE PARV	0.110	0	1	SAL ALAX	6.070	0	1	SAL LANA	-0.900	0	1
SAL RETI	9.510	0	1	PAR PALU	0.010	0	2	PEDIC SP	0.040	0	2
FUNGI	0.290	0	2	BASIDIOM	0.030	0	2	HEPATICS	0.0	0	2
BRY BIMU	0.0	0	1	CAM STEL	0.0	0	1	DIS INCL	0.0	0	1
ORE SEND	0.0	0	1	ORE UNCI	0.0	0	1	HYP LIND	0.0	0	2
TOM NITE	0.0	0	2								

C.3 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.)

In Hedysarum alpinum-Moss Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR
STEEL SP	0.340	1	0	CAR MEMB	3.960	1	1	EQU ARVE	3.000	1	1
EQU VARI	1.670	1	1	ARC ALPI	-0.180	1	1	GEN PROS	0.250	1	0
ARC LATI	-0.030	1	1	DES CAES	0.740	1	1	JUN CAST	0.240	1	1
LUZ PARV	0.250	1	0	HED ALPI	-34.250	1	1	EPI LATI	10.490	1	1
POL VIVI	-0.290	1	1	RUM ARCT	0.010	1	0	ANE PARV	0.060	1	1
THA ALPI	0.250	1	0	RUB ACAU	0.010	1	0	SAL ALAA	-5.320	1	1
SAL LANA	-0.650	1	1	SAL RETI	24.990	1	1	PAR KOTZ	0.240	1	1
SIE TOME	0.010	1	0	HEPATICS	0.0	1	1	MOSS SPP	-3.500	1	1
BLE TRIC	0.0	1	0	BRY PSEU	0.0	1	0	CAM STEL	0.0	1	0
DISTICHI	0.0	1	0	ORE REVO	0.0	1	0	HYP BAMB	0.0	1	0
PHI TOME	0.0	1	0	PLA ELLI	0.0	1	0	TOM NITE	0.0	1	1

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR.	SPECIES	COV DIF.	DISTB.	CONTR
BET GLAN	-0.010	0	1	ARN LESS	-0.010	0	1	AST SIBI	-0.750	0	1
ERI ERIO	-0.010	0	1	SIN LUGE	-0.010	0	1	SOL MULT	-0.010	0	1
CAR AURE	-0.010	0	1	CAR CAPI	-0.090	0	1	CAR SCIR	-0.010	0	1
ERI CALL	0.010	0	1	SHE CANA	-0.040	0	1	GEN PROP	-0.250	0	1
AGP VIOL	0.010	0	1	FES ALTA	-0.010	0	1	POA ALPN	-0.010	0	1
TRS SPIC	-0.010	0	1	JUN ALBE	-0.010	0	1	OXY OEFL	-0.090	0	1
TOF PUSI	-0.040	0	1	ZYG ELEG	-0.010	0	1	EPI ANGU	-0.010	0	1
PAR PALU	0.010	0	1	PEDIC SP	-0.040	0	1	FUNGI	-0.290	0	1
BASIDIOM	-0.040	0	1	HYP LIND	0.0	0	1				

C.4 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Hedysarum alpinum-Moss Tundra (n=3)

SPECIES	COV DIF	DISTB	CONTR.	SPECIES	COV DIF.	DISTB.	CONTR.	SPECIES	COV DIF.	DISTB	CONTR.
MER PANI	0.010	1	0	MYO ALPE	0.010	1	0	CER BEER	0.010	1	0
MIN BIFL	0.010	1	0	MIN STRI	0.010	1	0	SAG INTE	0.010	1	0
SAG LINN	0.010	1	0	SIL ACAU	0.010	1	0	ANT MONO	0.010	1	0
ARN ALPI	0.010	1	0	ART ARCT	0.140	1	0	ARI TILE	0.010	1	0
AST SIBI	-0.740	2	2	CRE NANA	0.010	1	0	ERI PURP	0.010	1	0
SEN LUGE	0.0	1	1	SOL MULT	0.0	1	1	RHO INTE	0.010	2	0
CAR PRAT	0.190	1	0	DRABA SP	0.140	1	0	DRA ALBE	0.010	1	0
CAR ATSQ	0.800	1	0	CAR AURE	0.030	1	1	CAR CAPI	-0.080	1	1
CAR MEMB	1.285	2	2	ERIOP SP	4.070	1	0	ERI SCHE	0.010	1	0
EQU ARVE	1.480	2	2	EQU SCIR	0.250	1	0	EQU VARI	6.310	2	2
ARC ALPI	-0.180	1	1	GEN PROP	-0.240	1	1	FES ALTA	0.030	1	1
POA ALPN	0.080	1	1	TRS SPIC	0.0	2	2	JUN BALT	7.050	1	0
JUN CAST	0.0	1	1	TRI PALU	0.010	1	0	HED ALPI	-34.490	1	1
OXY DEFL	-0.080	1	1	EPI LATI	0.0	2	2	CYP PASS	0.010	1	0
POL VIVI	-0.340	2	2	ANE PARV	-0.180	3	3	DRY SYLV	0.010	2	0
RUB ACAU	0.010	1	0	SIB PROC	0.010	1	0	POP BALS	0.010	1	0
SAL ALAX	-3.670	3	3	SAL ARCT	0.040	1	0	SAL GLAU	0.190	1	0
SAL MYRT	0.010	1	0	SAL PLAN	0.540	1	0	SAL A XP	0.010	2	0
SAL RETI	-8.837	3	3	PAR KOTZ	0.030	1	1	CET ISLA	0.010	1	0
CLA CARI	0.010	1	0	CLA PYXI	0.010	1	0	DAC BERI	0.010	1	0
PEL CANI	0.010	1	0	PEL RUFE	0.010	2	0	STE ALPI	0.010	1	0
MOSS SPP	14.397	3	3	BRYUM SP	0.0	1	0	BRY PSEU	0.0	1	0
CRA COMM	0.0	1	0	HYP BAMB	0.0	1	0	POL JUNI	0.010	1	0
RHA CANE	0.0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF.	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0.010	0	3	ARN LESS	-0.010	0	3	AST SIBI	-0.750	0	1
ERI ERIO	-0.010	0	3	SEN LUGE	-0.010	0	2	SOL MULT	-0.010	0	2
CAR AURE	-0.010	0	2	CAR CAPI	-0.090	0	2	CAR MEMB	-0.010	0	1
CAR SCIR	-0.010	0	3	ERI CALL	-0.010	0	3	SHE CANA	-0.040	0	3
EQU ARVE	-0.040	0	1	EQU VARI	-0.250	0	1	ARC ALPI	-0.180	0	2
GEN PROP	0.250	0	2	AGP VIOL	-0.010	0	3	ARC LATI	-0.040	0	3
DES CAES	0.010	0	3	FES ALTA	-0.010	0	2	POA ALPN	-0.010	0	2
TRS SPIC	-0.010	0	1	JUN CAST	-0.010	0	2	JUN ALBE	-0.010	0	3
HED ALPI	-34.500	0	2	OXY DEFL	-0.090	0	2	TOF PUSI	-0.040	0	3
ZYG ELEG	-0.010	0	3	EPI ANGU	-0.010	0	3	EPI LATI	-0.010	0	1
POL VIVI	-0.540	0	1	SAL LANA	-0.900	0	3	PAR KOTZ	-0.010	0	2
PAR PALU	-0.010	0	3	PEDIC SP	-0.040	0	3	FUNGI	-0.290	0	3
BASIDIOM	-0.040	0	3	HEPATICS	0.0	0	3	BRY BIMU	0.0	0	1
CAM STEL	0.0	0	1	DIS INCL	0.0	0	1	ORE SEND	0.0	0	1
ORE UNCI	0.0	0	1	HYP LIND	0.0	0	3	TOM NITE	0.0	0	3

C.5 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.) In Hedysarum alpinum-Moss Tundra (n=1)

SPECIES	CDV DIF	DISTB.	CONTR.	SPECIES	CDV DIF	DISTB	CONTR	SPECIES	CDV DIF	DISTB.	CONTR
ARN ALPI	0 010	1	0	AST SIBI	-0 150	1	1	CHR INTE	0 010	1	0
SAU ANGU	0.010	1	0	SOL MULT	0 0	1	1	CAR CAPI	-0.080	1	1
CAR SCIR	0 0	1	1	SHE CANA	20 010	1	1	EDU ARVE	-0 030	1	1
EQU VARI	-0.060	1	1	ARC ALPI	-0 050	1	1	GEN PROP	-0.210	1	1
DES CAES	0.0	1	1	FES ALTA	0 0	1	1	PDA ALPN	0 0	1	1
TRS SPIC	0 030	1	1	JUN BALT	0 010	1	0	HED ALPI	-33.600	1	1
DXY DEFL	1 010	1	1	TOF PUSI	-0 030	1	1	EPI LATI	5.550	1	1
PDL VIVI	-0 450	1	1	ANE PARV	0 710	1	1	ORY INTE	5.920	1	0
POT FRUT	0.650	1	0	PDP BALS	0 600	1	0	SAL ALAX	-1.120	1	1
SAL MYRT	0.010	1	0	SAL RETI	-9.070	1	1	PAR FIMB	0 190	1	0
PAR PALU	0 0	1	1	SAX AIZO	0 010	1	0	SAX OPPO	0.010	1	0
SEL SELA	0 010	1	0	BASIDIOM	0 210	1	1	PEL CANI	1 210	1	0
MOSS SPP	8.500	1	1	BRA GROE	0 0	1	0	BRA SALE	0 0	1	0
CAM POLY	0.0	1	0	DIT FLEX	0.0	1	0	ORE UNCI	0.0	1	1
TDR NORV	0.0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	CDV DIF	DISTB	CONTR	SPECIES	CDV DIF	DISTB.	CONTR	SPECIES	CDV DIF.	DISTB	CONTR
BET GLAN	-0 010	0	1	ARN LESS	-0 010	0	1	ERI ERID	-0 010	0	1
SEN LUGE	-0 010	0	1	CAR AURE	-0.010	0	1	CAR MEMB	-0 010	0	1
ERI CALL	-0 010	0	1	AGP VIDL	-0 010	0	1	ARC LATI	-0 040	0	1
JUN CAST	-0 010	0	1	JUN ALBE	-0 010	0	1	ZYG ELEG	-0.010	0	1
EPI ANGU	-0 010	0	1	SAL LANA	-0 900	0	1	PAR KOTZ	-0 010	0	1
PEOIC SP	-0.040	0	1	FUNGI	-0 290	0	1	HEPATICS	0 0	0	1
BRY BIMU	0 0	0	1	CAM STEL	0 0	0	1	DIS INCL	0 0	0	1
DRE SEND	0 0	0	1	HYP LINO	0 0	0	1	TOM NITE	0 0	0	1

D.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.) In Carex membranacea-Kobresia simpliciuscula Tundra (n=1)

SPECIES	CDV DIF	DISTB	CONTR	SPECIES	CDV DIF	DISTB.	CONTR	SPECIES	CDV.DIF	DISTB	CONTR.
MIN ARCT	0 0	1	1	MIN R EL	2.570	1	1	STE LAET	0.010	1	0
SEN CYMB	0 0	1	1	BRA PURP	0.090	1	0	DRA CDRY	0.010	1	0
POA SP	0 440	1	0	JUN ALBE	-0 530	1	1	PAP KEEL	1 210	1	0
PDL VIVI	-0 030	1	1	AND CHAM	0 010	1	0	DRY INTE	-0 200	1	1
SAI ALAX	7 590	1	0	SAL ARCT	0 710	1	1	SAL DUDG	0 010	1	0
SAX OPPO	0 010	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	CDV DIF	DISTB	CONTR	SPECIES	CDV.DIF	DISTB	CONTR	SPECIES	CDV DIF.	DISTB.	CONTR
SEN ATRO	-0 010	0	1	CAR MEMB	-11 520	0	1	CAR MISA	-9 570	0	1
CAR PODD	-9.110	0	1	ERI ANGU	-2 020	0	1	ERI CALL	-0.250	0	1
KDB SIMP	-3 150	0	1	CAS TETR	-0 010	0	1	PAP RADI	-0 040	0	1
THA ALPI	-0 140	0	1	DRY OCTO	-0 140	0	1	SAL RETI	-0 140	0	1
PEO LANA	-0 040	0	1	TER ALGA	-0 140	0	1	CET NIVA	-0 040	0	1
CET TILE	-0 010	0	1	SDL BISP	-0 040	0	1	SOIL LIC	-1.100	0	1
HEPATICS	-0 090	0	1	MOSS SPP	-1.920	0	1	CAM STEL	-0.010	0	1
DIT FLEX	-0 010	0	1	HYP BAMB	-0.010	0	1				

D.2 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.) In Carex membranacea-Kobresia simpliciuscula Tundra (n=1)

SPECIES	CDV DIF	DISTB	CONTR	SPECIES	CDV.DIF	DISTB.	CONTR.	SPECIES	CDV.DIF.	DISTB	CONTR.
MIN ARCT	0 0	1	1	MIN R EL	0 690	1	1	SEN CYMB	0 180	1	1
BRA PURP	0 040	1	0	DRA CDRY	0 040	1	0	PAR NUDI	0 010	1	0
CAR ATFU	0 010	1	0	CAR MEMB	-11 510	1	1	CAR MISA	-6 530	1	1
ERI ANGU	-2 010	1	1	ERI CALL	-0 240	1	1	KDB SIMP	-1 590	1	1
PDA SP	0 010	1	0	JUN BIGL	0 010	1	0	JUN ALBE	-0 100	1	1
LLD SERO	0 010	1	0	TDF PUSI	0 010	1	0	PAPAV SP	0.010	1	0
PAP KEEL	0 040	1	0	PDL VIVI	0 210	1	1	AND CHAM	0.010	1	0
THA ALPI	-0 130	1	1	DRY INTE	B 710	1	1	SAL ALAX	11 690	1	0
SAL ARCT	1 170	1	1	SAL DRDG	0 950	1	0	SAL RETI	2 B10	1	1
SAX OPPO	0 140	1	0	PEO LANA	0 210	1	1	SOLARINA	0.010	1	0
SOIL LIC	2 510	1	1	HEPATICS	0 0	1	1	MOSS SPP	-1.BB0	1	1
DIT FLEX	-0 010	1	1	DRE REVD	0 0	1	0				

--------- IN CONTROLS BUT NOT IN DISTURBANCES -- -

SPECIES	COV DIF	DISTB.	CONTR	SPECIES	CDV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.
SEN ATRO	-0 010	0	1	CAR PODD	-9 110	0	1	CAS TETR	-0 010	0	1
PAP RADI	-0 040	0	1	DRY OCTO	-0 140	0	1	TER ALGA	-0 140	0	1
CET NIVA	-0 040	0	1	CET TILE	-0 010	0	1	SOL BISP	-0 040	0	1
CAM STEL	0 010	0	1	HYP BAMB	-0 010	0	1				

E.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Salix barrattiana-Moss Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ANT SIOL	0.010	1	0	AST SIBI	0.010	1	0	CRE NANA	0.010	1	0
ERI HUMI	0.290	1	0	SOL MULT	0.010	1	0	EQU ARVE	-4.060	1	1
EQU VARI	0.010	1	0	ARC ALPI	2.140	1	0	GEN PROS	0.040	1	0
GEN PROP	-0.030	1	1	ARC LATI	-1.520	1	1	DES CAES	-0.560	1	1
EPI ANGU	0.010	1	0	POL VIVI	0.180	1	1	ANE PARV	-0.550	1	1
DRY INTE	0.010	1	0	SAL ALAX	13.520	1	0	SAL GLAU	8.350	1	0
SAL MYRT	0.010	1	0	SAL A XP	0.140	1	0	SAL RETI	2.510	1	1
PAR KOTZ	-0.080	1	1	CLADO SP	0.250	1	0	PEL RUFE	0.090	1	0
SOL SACC	0.250	1	0	MOSS SPP	11.990	1	1	BRYUM SP	0.0	1	0
CAM POLY	0.0	1	0	CER PURP	0.0	1	0	RHA CANE	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MER PANI	-7.050	0	1	MYO ALPE	-0.250	0	1	CER BEER	0.090	0	1
STELL SP	-0.010	0	1	SIE LAET	0.190	0	1	ART TILE	-0.600	0	1
PET FRIG	-1.870	0	1	SEN LUGE	-0.140	0	1	RHO INTE	-0.140	0	1
CAR PRAT	-0.010	0	1	COMPO SP	-0.900	0	1	DRA LONG	-0.090	0	1
EUT EDWA	-0.010	0	1	AST UMBE	-1.050	0	1	POL ACUT	-7.510	0	1
RUM ARCT	-0.750	0	1	CLA TUBE	-0.010	0	1	ACO DELP	-2.900	0	1
RAN SULP	0.010	0	1	THA ALPI	-2.580	0	1	SAL BARR	-29.000	0	1
CHR TETR	0.010	0	1	PED SUDE	-0.010	0	1	VAL CAPI	-0.010	0	1
VIOLA SP	-1.920	0	1	CET PINA	-0.040	0	1	CLA CHLO	-0.140	0	1
PEL APHT	-0.010	0	1	BRA STAR	0.0	0	1	BRY PSEU	0.0	0	1
ORE UNCI	0.0	0	1	HYP LIND	0.0	0	1	TOR NORV	0.0	0	1

E.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In Salix barrattiana-Moss Tundra (n=3)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0.040	1	0	MER PANI	-7.040	1	1	CER BEER	0.080	1	1
MIN BIFL	0.075	2	0	SIL ACAU	0.040	1	0	ANT MONO	0.025	2	0
ARN ALPI	0.010	1	0	ARN LESS	0.010	1	0	ART ARCT	0.010	1	0
ERI HUMI	0.050	2	0	PET FRIG	-1.830	1	1	SAU ANGU	0.010	1	0
SEN LUGE	0.130	1	1	SOL MULT	0.010	1	0	RHO INTE	0.190	2	2
CAR A AD	28.500	1	1	CAR MEMB	0.010	1	0	CAR MICH	0.010	1	0
CAR SCIR	0.010	1	0	EQU SCIR	1.215	2	0	ARC ALPI	0.010	1	0
GEN PROS	0.010	1	0	-GEN PROP	-0.030	1	1	DES CAES	14.550	2	2
FES ALTA	0.090	1	0	HED ALPI	0.010	1	0	ZYG ELEG	0.010	1	0
EPI ANGU	3.970	1	0	EPI LATI	0.065	2	0	BOT LUNA	0.040	1	0
OXY DIGY	0.010	1	0	POL VIVE	0.050	2	2	ANE NARC	0.010	1	0
ANE PARV	-0.525	2	2	THA ALPI	-2.570	1	1	DRY OCTO	0.010	1	0
POT FRUT	0.365	2	1	RUB ACAU	0.010	1	0	SIB PRUC	0.010	1	0
SAL ALAX	0.040	1	0	SAL ARCT	0.140	1	0	SAL BARR	-28.415	2	2
SAL GLAU	0.365	2	1	SAL MYRT	0.0	1	1	SAL PLAN	0.115	2	0
SAL A XP	0.010	1	0	SAL RETI	-3.397	3	3	PAR KOTZ	-0.080	1	1
SEL SELA	0.010	1	0	CET CUCU	0.010	1	0	CET DELI	0.010	1	0
CLADO SP	0.290	1	0	CLA POCI	0.040	1	0	DAC BERI	0.010	1	0
PEL RUFE	0.250	1	0	SOL SACC	0.040	1	0	STE TOME	0.140	1	0
MOSS SPP	-7.853	3	3	BRACH SP	0.0	1	0	BRY PSEU	0.0	1	0
DRE REVO	0.0	1	0	PTA ELLI	0.0	1	0	RHA CANE	0.0	1	0
SPHAGNUM	0.0	1	0	TOM NITE	0.0	1	0	CIN STYG	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ---

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MER PANI	-7.050	0	1	MYO ALPE	-0.250	0	2	CER BEER	-0.090	0	1
STELL SP	-0.010	0	2	SIE LAET	-0.190	0	2	ART TILE	-0.600	0	2
PET FRIG	1.870	0	1	SEN LUGE	-0.140	0	1	CAR PRAT	-0.010	0	2
COMPO SP	-0.900	0	2	DRA LONG	0.090	0	2	EUT EDWA	-0.010	0	2
EQU ARVE	-4.070	0	2	GEN PROP	0.040	0	1	ARC LATI	-2.120	0	2
AST UMBE	-1.050	0	2	POL ACUT	-7.510	0	2	RUM ARCT	-0.750	0	2
CLA TUBE	-0.010	0	2	ACO DELP	-2.900	0	2	RAN SULP	0.010	0	2
THA ALPI	2.580	0	1	SAL BARR	-29.000	0	1	CHR TETR	-0.010	0	2
PAR KOTZ	0.090	0	1	PED SUDE	0.010	0	2	VAL CAPI	-0.010	0	2
VIOLA SP	1.920	0	2	CET PINA	0.040	0	2	CLA CHLO	-0.140	0	2
PEL APHT	0.010	0	2	BRA STAR	0.0	0	2	BRY PSEU	0.0	0	2
ORE UNCI	0.0	0	2	HYP LIND	0.0	0	2	TOR NORV	0.0	0	2

E.3 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.)

In Salix barrattiana-Moss Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MER PANI	-7.040	1	1	CER BEER	-0.080	1	1	SIL ACAU	0.250	1	0
STE LAET	-0.100	1	1	ART TILE	-0.590	1	1	ERI HUMI	0.010	1	0
PET FRIG	0.050	1	1	SEN LUGE	0.050	1	1	RHO INTE	-0.130	1	1
CAR PRAT	0.0	1	1	CAR MEMB	16.500	1	0	CAR PODO	0.140	1	0
CAR SCIR	0.750	1	0	EQU ARVE	0.930	1	1	EQU VARI	0.140	1	0
GEN PROS	0.050	2	0	GEN PROP	0.275	2	2	ARC LATI	-1.730	1	1
FES ALTA	0.190	1	0	POA PAUC	0.800	1	0	EPI ANAG	0.010	1	0
EPI LATI	5.000	1	0	POL ACUT	-7.320	1	1	POL VIVI	0.005	2	2
RUM ARCT	-0.710	1	1	CLA TUBE	0.0	1	1	ACO DELP	-2.890	1	1
ANE NARC	0.140	1	0	ANE PARV	-0.350	2	2	THA ALPI	-2.315	2	2
DRY INTE	0.010	1	0	SAL BARR	-27.455	2	2	SAL PLAN	0.495	2	0
SAL A XP	0.115	2	0	SAL RETI	16.675	2	2	CHR TETR	0.080	1	1
PAR KOTZ	0.350	1	1	SAX AIZO	0.090	1	0	SAX OPPO	0.010	1	0
PED CAPI	0.090	1	0	PED SUDE	0.0	1	1	VAL CAPI	0.0	1	1
CET LAEV	0.090	1	0	CLA POCI	0.090	1	0	PEL RUFE	0.040	1	0
SOL BISP	0.090	1	0	HEPATICS	0.040	2	0	MOSS SPP	11.960	2	2
BRA SALE	0.0	1	0	DISTICHI	0.0	1	0	HYP BAMB	0.0	1	0
POH CRUD	0.0	1	0	TOR TORT	0.0	1	0				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MER PANI	-7.050	0	1	MYO ALPE	-0.250	0	2	CER BEER	-0.090	0	1
STELL SP	-0.010	0	2	STE LAET	-0.190	0	1	ART TILE	-0.600	0	1
PET FRIG	-1.870	0	1	SEN LUGE	-0.140	0	1	RHO INTE	-0.140	0	1
CAR PRAT	-0.010	0	1	COMPO SP	-0.900	0	2	DRA LONG	-0.090	0	2
EUT EDWA	-0.010	0	2	EQU ARVE	-4.070	0	1	ARC LATI	-2.120	0	1
DES CAES	-1.920	0	2	AST UMBE	-1.050	0	2	POL ACUT	-7.510	0	1
RUM ARCT	-0.750	0	1	CLA TUBE	-0.010	0	1	ACO DELP	-2.900	0	1
RAN SULP	0.010	0	3	CHR TETR	-0.010	0	1	PAR KOTZ	-0.090	0	1
PED SUDE	-0.010	0	1	VAL CAPI	-0.010	0	1	VIOLA SP	-1.920	0	2
CET PINA	-0.040	0	2	CLA CHLO	-0.140	0	2	PEL APHT	-0.010	0	2
BRA STAR	0.0	0	2	BRYACEAE	0.0	0	1	BRY PSEU	0.0	0	3
CAM STEL	0.0	0	1	ORE UNCI	0.0	0	2	HYP BAMB	0.0	0	1
HYP LIND	0.0	0	2	PHI TOME	0.0	0	1	POH CRUD	0.0	0	1
TOR NORV	0.0	0	2								

E.4 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Salix barrattiana-Moss Tundra (n=3)

SPECIES	COV.DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MER PANI	-7.045	2	2	CER BEER	0.085	2	2	MIN ROSS	0.010	1	0
SIL ACAU	0.003	3	0	STE LAET	-0.190	1	1	ANT MONO	0.0	1	0
ARN ALPI	0.0	1	0	ARN LOUI	0.0	1	0	AST SIBI	0.010	1	0
CRE NANA	0.003	3	0	ERI HUMI	0.0	2	0	PET FRIG	-1.860	1	1
PET HYPE	0.0	1	0	SEN LUGE	-0.140	2	2	STN CYMB	0.005	2	0
SOL MULT	0.010	1	0	TAR ALAS	0.0	1	0	RHO INTE	-0.140	2	2
CAR ATSO	0.0	2	0	CAR SCIR	0.005	2	0	SHE CANA	0.010	1	0
EQU SCIR	0.005	2	0	EQU VARI	0.005	2	0	ARC ALPI	0.010	1	0
GEN PROP	-0.040	2	2	GRAMINEA	1.100	1	0	AGP VIOL	0.010	1	0
ARC LATI	-2.115	2	2	DES CAES	-1.920	2	2	FES ALTA	0.003	3	0
HIE DOOR	0.0	1	0	TRS SPIC	0.005	2	0	OXY DEFL	0.010	1	0
EPI ANGO	0.0	1	0	EPI LATI	1.717	3	0	ANE PARV	-0.637	3	3
THA ALPI	-2.570	1	1	DRY INTE	0.0	1	0	DRY OCTO	0.010	1	0
DRY SYLV	0.0	1	0	RUB ACAU	0.0	2	0	SIB PROC	0.0	1	0
POP BALS	0.0	1	0	SAL ALAX	0.005	2	0	SAL ARCT	0.005	2	0
SAL GLAU	0.003	3	0	SAL MYRT	0.0	1	0	SAL PLAN	0.550	2	0
SAL A XP	0.643	3	0	SAL RETI	4.397	3	3	PAR KOTZ	-0.090	1	1
SAX AIZO	0.010	1	0	SAX OPPO	0.005	2	0	VAL CAPI	-0.010	1	1
MIS LICH	0.010	2	0	CET CUCU	0.0	1	0	CET ISLA	0.0	2	0
CET NIVA	0.0	2	0	CET TILE	0.0	1	0	CLA STEI	0.0	1	0
CLADO SP	0.0	1	0	CLA POCI	0.0	1	0	DAC DFRI	0.0	2	0
PET CANI	0.0	2	0	PEL RUFE	0.0	1	0	SOL BISP	0.0	1	0
SOL SACC	0.0	1	0	STE ALPI	0.0	1	0	STE SAXA	0.0	1	0
STE TOME	0.0	1	0	MOSS SPP	0.690	3	3	BRA SALE	0.0	1	0
DII FLEX	0.0	1	0	RHA CANE	0.0	2	0				

-------- IN CONTROLS BUT NOT IN DISTURBANCES --

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MER PANI	-7.050	0	1	MYO ALPE	0.250	0	3	CLR BEER	-0.090	0	1
STELL SP	-0.010	0	3	STE LAET	0.190	0	2	ART TILE	-0.600	0	3
PET FRIG	-1.870	0	2	SEN LUGE	0.140	0	1	RHO INTE	-0.140	0	1
CAR PRAT	-0.010	0	3	COMPO SP	-0.900	0	3	ORA LONG	-0.090	0	3
EUT EDWA	0.010	0	3	EQU ARVE	-4.070	0	3	GEN PROP	-0.040	0	1
ARC LATI	2.120	0	1	DES CAES	-1.920	0	1	AST UMBE	1.050	0	3
POL ACUT	-7.510	0	3	POL VIVI	-0.190	0	3	RUM ARCT	-0.750	0	3
CLA TUBE	0.010	0	3	ACO DELP	-2.900	0	3	RAN SULP	0.010	0	3
THA ALPI	-2.580	0	2	SAL BARR	-29.000	0	3	CHR TETR	-0.010	0	3
PAR KOTZ	-0.090	0	2	PED SUDE	-0.010	0	3	VAI CAPI	-0.010	0	2
VIOLA SP	-1.920	0	3	CET PINA	-0.040	0	3	CLA CHLO	0.140	0	3
PEL APHT	-0.010	0	3	BRA STAR	0.0	0	3	BRYACLAE	0.0	0	3
BRY PSEU	0.0	0	6	CAM STEL	0.0	0	3	ORE UNCI	0.0	0	3
HYP BAMB	0.0	0	3	HYP LIND	0.0	0	3	PHI TOME	0.0	0	3
POH CRUD	0.0	0	3	TOR NORV	0.0	0	3				

E.5 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.)

In Salix barrattiana-Moss Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
CLR BEER	0.080	1	1	STE LAET	-0.180	2	2	ART TILE	-0.590	1	1
AST SIBI	0.010	1	0	CAR MEMB	0.010	1	0	CAR PODO	0.010	1	0
EQU SCIR	0.010	2	0	GEN PROS	0.010	1	0	ARC LATI	-2.110	1	1
DES CAES	-1.910	1	1	FES ALTA	0.010	1	0	POA ALPN	20.500	1	0
TRS SPIC	5.150	1	0	AST ALPI	0.010	1	0	EPI ANGU	3.040	1	0
POL VIVI	-0.180	1	1	THA ALPI	-2.570	1	1	RUB ACAU	0.010	1	0
SAL RETI	-0.940	2	2	PAR KOTZ	-0.080	1	1	MIS LICH	39.500	1	0
CET ERIC	0.0	1	0	CET ISLA	0.0	1	0	CLA CARI	0.0	2	0
CLA CUCC	0.0	1	0	CLA PYXI	0.0	2	0	PSO HYPN	0.0	1	0
RIN TURF	0.0	1	0	MOSS SPP	10.815	2	2	ENC AFFI	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF	DISTB	CONTR.	SPECIES	COV DIF	DISTB	CONTR
MER PANI	-7.050	0	2	MYO ALPE	-0.250	0	2	CER BEER	-0.090	0	1
STELL SP	-0.010	0	2	ART TILE	-0.600	0	1	PET FRIG	-1.870	0	2
SEN FUGE	-0.140	0	2	RHO INTE	-0.140	0	2	CAR PRAT	-0.010	0	2
COMPO SP	-0.900	0	2	ORA LONG	-0.090	0	2	EUT EDWA	-0.010	0	2
EQU ARVE	-4.070	0	2	GEN PROP	-0.040	0	2	ARC LATI	-2.120	0	1
DES CAES	-1.920	0	1	AST UMBE	-1.050	0	2	POL ACUT	-7.510	0	2
POL VIVI	-0.190	0	1	RUM ARCT	-0.750	0	2	CLA TUBE	-0.010	0	2
ACO DELP	-2.900	0	2	ANE PARV	-0.640	0	2	RAN SULP	-0.010	0	2
THA ALPI	-2.580	0	1	SAL BARR	-29.000	0	2	CHR TETR	-0.010	0	2
PAR KOTZ	-0.090	0	1	PED SUDE	-0.010	0	2	VAL CAPI	-0.010	0	2
VIOLA SP	-1.920	0	2	CET PINA	-0.040	0	2	CLA CHLO	-0.140	0	2
PEL APHT	-0.010	0	2	BRA STAR	0.0	0	2	BRYACLAE	0.0	0	2
BRY PSEU	0.0	0	4	CAM STEL	0.0	0	2	ORE UNCI	0.0	0	2
HYP BAMB	0.0	0	2	HYP LIND	0.0	0	2	PHI TOME	0.0	0	2
POH CRUD	0.0	0	2	TOR NORV	0.0	0	2				

F.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)
In *Salix reticulata*-*Salix lanata* Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
AST SIBI	0.810	1	1	EQU ARVE	0.010	1	0	EQU VARI	-0.740	1	1
ARC ALPI	0.010	1	0	POA ALPN	0.010	1	0	TRS SPIC	0.040	1	0
HED ALPI	-2.030	1	1	HED MACK	2.090	1	0	OXY DEFL	-0.050	1	1
EPI LATI	0.250	1	1	POL VIVI	-0.160	1	1	ANE PARV	-0.100	1	1
DRY INTE	0.010	1	0	POT FRUT	0.0	1	1	SAL ALAX	11.500	1	1
SAL GLAU	4.800	1	0	SAL RETI	-57.100	1	1	PAR KOTZ	-0.030	1	1
SAX AIZO	0.010	1	0	CET CUCU	0.010	1	0	CET DELI	0.010	1	0
PEL RUFE	9.420	1	0	MOSS SPP	-4.520	1	1				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV.DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
CAR MEMB	0.140	0	1	CAR SCIR	-0.140	0	1	ARC LATI	-0.090	0	1
SAL BARR	-0.010	0	1	SAL LANA	-10.300	0	1	SAL MYRT	-0.010	0	1

F.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)
In *Salix reticulata*-*Salix lanata* Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN R EL	0.010	1	0	SIL ACAU	0.010	1	0	ANT MONO	0.010	1	0
ARN ALPI	0.010	1	0	ERI HUMI	0.010	1	0	PET TRIG	0.010	1	0
SEN LUGE	0.010	1	0	SEN CYMB	0.010	1	0	SOL MOLT	0.010	1	0
CAR MEMB	-0.130	1	1	CAR SCIR	1.780	1	1	ERI ANGO	0.010	1	0
EQU ARVE	0.010	1	0	EQU SCIR	0.010	1	0	ARC ALPI	0.010	1	0
ARC LATI	-0.080	1	1	HED ALPI	-2.110	1	1	LLO SERO	0.010	1	0
EPI LATI	-0.030	1	1	OXY DIGY	1.920	1	0	POL VIVI	-0.240	1	1
ANE PARV	-0.180	1	1	THA ALPI	0.010	1	0	DRY INTE	0.010	1	0
POT FRUT	1.910	1	1	SAL ALAX	10.490	1	1	SAL GLAU	0.010	1	0
SAL PLAN	0.250	1	0	SAL RETI	-57.660	1	1	PAR KOTZ	-0.030	1	1
SAX AIZO	0.250	1	0	SAX OPPO	0.010	1	0	MIS LICH	0.010	1	0
PEL RUFE	0.0	1	0	SOL BISP	0.0	1	0	MOSS SPP	-1.800	1	1
BRACH SP	0.0	1	0	BRYUM SP	0.0	1	0	CAM STEL	0.0	1	0
DIT FLEX	0.0	1	0	DRE REVO	0.0	1	0	HYP BAMB	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ---

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
AST SIBI	0.040	0	1	EQU VARI	0.750	0	1	OXY DEFL	-0.090	0	1
SAL BARR	0.010	0	1	SAL LANA	-10.300	0	1	SAL MYRT	-0.010	0	1

F.3 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)
In *Salix reticulata*-*Salix lanata* Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB.	CONTR
MIN R EL	0.140	1	0	SIL ACAU	0.190	1	0	ANT MONO	0.040	1	0
ARN ALPI	0.040	1	0	CRE NANA	0.340	1	0	ERI HUMI	0.010	1	0
SOL MULT	0.010	1	0	BRA PURP	0.010	1	0	CAREX SP	0.140	1	0
CAR NARO	1.260	1	0	ARC ALPI	0.010	1	0	DES CAES	0.010	1	0
POA ALPN	0.390	1	0	EPI ANGU	0.010	1	0	POL VIVI	-0.110	1	1
ANE PARV	0.460	1	1	DRY INTE	0.140	1	0	SAL ALAX	2.240	1	1
SAL GLAU	7.790	1	0	SAL A XP	0.190	1	0	SAL RETI	-56.740	1	1
SAX AIZO	0.190	1	0	SAX OPPO	1.970	1	0	PEL RUFE	0.010	1	0
MOSS SPP	6.810	1	1	BRY RECO	0.0	1	0	BRYUM SP	0.0	1	0
URE REVO	0.0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
AST SIBI	-0.040	0	1	CAR MEMB	-0.140	0	1	CAR SCIR	-0.140	0	1
EQU VARI	-0.750	0	1	ARC LATI	-0.090	0	1	HED ALPI	-2.120	0	1
OXY DEFL	-0.090	0	1	EPI LATI	-0.040	0	1	POT FRUT	-0.010	0	1
SAL BARR	-0.010	0	1	SAL LANA	-10.300	0	1	SAL MYRT	-0.010	0	1
PAR KOTZ	0.040	0	1								

F.4 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.)
In *Salix reticulata*-*Salix lanata* Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ANT MONO	1.100	1	0	AST SIBI	-0.030	1	1	SEN LUGE	0.250	1	0
SOL MULT	3.040	1	0	CAR SCIR	3.395	2	2	EQU ARVE	0.750	1	0
EQU SCIR	0.380	2	0	ARC ALPI	0.010	1	0	GEN PROS	0.010	1	0
FES ALTA	20.500	1	0	TRS SPIC	0.965	2	0	HED ALPI	-1.990	2	2
EPI ANGU	0.250	1	0	POL VIVI	-0.240	1	1	PYR SECU	0.250	1	0
ANE PARV	0.060	2	2	THA ALPI	0.130	2	0	RUB ACAU	0.010	1	0
SAL GLAU	0.010	1	0	SAL A XP	0.130	2	0	SAL RETI	-55.050	2	2
MIS LICH	5.150	1	0	CLADO SP	0.010	1	0	CLA POCI	10.250	2	0
CLA PYXI	20.500	1	0	PEL RUFE	0.0	1	0	SOL BISP	0.0	1	0
MOSS SPP	17.940	1	1								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ---

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
AST SIBI	-0.040	0	1	CAR MEMB	-0.140	0	2	EQU VARI	-0.750	0	2
ARC LATI	0.090	0	2	OXY DEFL	-0.090	0	2	EPI LATI	-0.040	0	2
POL VIVI	-0.250	0	1	POT FRUT	-0.010	0	2	SAL ALAX	-0.010	0	2
SAL BARR	-0.010	0	2	SAL LANA	-10.300	0	2	SAL MYRT	-0.010	0	2
PAR KOTZ	-0.040	0	2	MOSS SPP	-6.950	0	1				

G.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Salix polaris-Dactylina beringica Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
CER BEER	0 010	1	0	MIN BIFL	0 180	1	1	ANT MONO	-0 210	1	1
ART ARCT	-0 240	1	1	ART TILE	0 010	1	0	ERI HUMI	0 040	1	0
PET HYPE	0 010	1	0	SEN LUGE	0 010	1	0	RHO INTE	0 0	1	1
ALO ALPI	0 010	1	0	ARC LATI	0 010	1	0	FES ALTA	0 010	1	0
POA ARCT	43 650	1	1	TRS SPIC	5.560	1	0	EPI ANGU	0 010	1	0
EPI LATI	0 010	1	0	ANE PARV	0 010	1	0	SIB PROC	0 0	1	1
SAL ALAX	0 010	1	0	SAL ARCT	0 010	1	0	SAL PLAN	0 010	1	0
SAL RETI	0 0	1	1	PAR KOIZ	0 010	1	0	PEL CANI	0 390	1	0
MOSS SPP	7 510	1	0	BRACH SP	0 010	1	0	CER PURP	0 0	1	0
DIS CAPI	0 0	1	0	DIT FLEX	0 0	1	0				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
PET FRIG	-0 040	0	1	CAR PODO	-0 190	0	1	GEN GLAU	-0 010	0	1
LUZ ARCU	-0 040	0	1	LUZ PARV	-0 040	0	1	POL ACUT	-0 010	0	1
ANE NARC	-0 190	0	1	RAN ESCH	-0 010	0	1	SAL POLA	-29 000	0	1
PED SUDE	-0 010	0	1	CET ISLA	-0 250	0	1	CET NIVA	-0 090	0	1
CET RICH	-0 040	0	1	CLA MITI	-0 540	0	1	CLA COCC	-0 250	0	1
CLA ECMO	-0 800	0	1	CLA GONE	-0 250	0	1	DAC BERI	-0 900	0	1
NEP ARCT	-0 090	0	1	NEP EXPA	-0 800	0	1	PEL APHT	-0 540	0	1
SOL CROC	-0 090	0	1	STE ALPI	-0 340	0	1	PLE SCHR	0.0	0	1
POL COMM	0 0	0	1	POL STRI	0 0	0	1	RHA CANE	0.0	0	1

G.2 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.)

In Salix polaris-Dactylina beringica Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0 010	1	0	CER BEER	0 010	1	0	MIN BIFL	0 080	1	1
ANT MONO	0 090	1	1	ART ARCT	6 280	1	1	PET HYPE	0 010	1	0
SEN FRIA	0 140	1	0	RHO INTE	0 030	1	1	CAR PHAE	0 190	1	0
CAR PODO	1 220	1	1	CAR PYRE	0 090	1	0	VAC VITI	0 010	1	0
GEN GLAU	0 890	1	1	DES CAES	4.800	1	0	FES ALTA	0 010	1	0
TRS SPIC	3 460	1	0	JUN BALT	0 010	1	0	LUZULA	0 700	1	0
LUZ PARV	2 400	1	1	EPI ANGU	0 290	1	0	POL ACUT	0 0	1	1
POL VIVI	0 090	1	0	ANE NARC	-0 180	1	1	ANE PARV	0 040	1	0
SIB PROC	6 990	1	1	SAL ARCT	10 950	1	0	SAL PLAN	4 850	1	0
SAL RETI	0 0	1	1	VER WORM	1 410	1	0	BASIDIOM	1 050	1	0
CET ISLA	0 390	1	1	CET RICH	0.100	1	1	CLA ARBU	0 090	1	0
CLA BACL	0 010	1	0	CLA COCC	0 0	1	1	CLA ECMO	-0 660	1	1
CLA MACR	0 250	1	0	CLA SUOF	0 090	1	0	DAC BERI	-0 810	1	1
NEP ARCT	-0 080	1	1	PEL APHT	1.940	1	1	PEL PULV	2 480	1	0
PSO HYPN	0 190	1	0	SOL CROC	0 410	1	1	STE ALPI	1 220	1	1
SOIL LIC	8 950	1	0	LEC CRUS	0 090	1	0	HEPATICS	0 0	1	0
MOSS SPP	7 510	1	0	POLYT SP	0 900	1	0	AUL PALU	0 0	1	0
CON TETR	0 0	1	0	DICRANUM	0 0	1	0	ORE UNCI	0 0	1	0
POL JUNI	0.0	1	0	POL PILI	0.0	1	0	RHA CANE	0 0	1	1

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
PET FRIG	0 040	0	1	POA ARCT	0 850	0	1	LUZ ARCU	0 040	0	1
RAN ESCH	0 010	0	1	SAL POLA	-29 000	0	1	PED SUDE	0 010	0	1
CET NIVA	0 090	0	1	CLA MITI	-0 540	0	1	CLA GONE	-0 250	0	1
NEP EXPA	0 800	0	1	PLE SCHR	0 0	0	1	POL COMM	0 0	0	1
POL STRI	0 0	0	1								

G.3 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Salix polaris-Dactylina beringica Tundra (n=2)

SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB.	CONTR
CER BEER	0 010	3	0	MIN BIFL	0 0	2	2	ANT MONO	-0.240	2	2
ART ARCT	-0 240	2	2	PET FRIG	-0 030	1	1	SEN LUGE	0.010	1	0
TAR ALAS	0 010	1	0	RHO INTE	0 0	1	1	CAR PODO	-0.180	1	1
EQU ARVE	0 010	1	0	GEN GLAU	0 0	1	1	HIE ODOR	0.010	1	0
TRS SPIC	0 010	2	0	EPILO SP	0 010	1	0	LLO SERO	0.010	1	0
EPI LATI	0 010	2	0	RUM ARCT	0 010	1	0	CLA TUBE	0.010	1	0
ANE NARC	-0 180	2	2	RAN ESCH	0 0	2	2	SIB PROC	0 0	2	2
SAL ALAX	0.010	2	0	SAL PLAN	0 010	1	0	SAL POLA	-28.990	2	2
SAL A KP	0 010	1	0	SAL RETI	0 0	1	1	CET ISLA	-0.240	1	1
CLA POCI	0 010	1	0	PAN PEZI	0 0	1	0	PEL CANI	0 0	1	0
PEL RUFE	0 010	1	0	STE TOME	0 010	1	0	TON LOBU	0 0	1	0
PELTI SP	0 0	1	0	POG ALPI	0 0	1	0	RHA CANE	0 0	2	2

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR
PET FRIG	-0 040	0	1	RHO INTE	-0 010	0	1	CAR PODO	-0 190	0	1
GEN GLAU	-0 010	0	1	POA ARCT	-0 850	0	2	LUZ ARCU	-0 040	0	2
LUZ PARV	-0 040	0	2	POL ACUT	-0 010	0	2	SAL RETI	-0 010	0	1
PED SUDE	-0 010	0	2	CET ISLA	-0 250	0	1	CET NIVA	-0 090	0	2
CET RICH	-0 040	0	2	CLA MITI	-0 540	0	2	CLA COCC	-0.250	0	2
CLA ECMO	-0 800	0	2	CLA GONE	-0 250	0	2	DAC BERI	-0 900	0	2
NEP ARCT	-0 090	0	2	NEP EXPA	-0 800	0	2	PEL APHT	-0 540	0	2
SOL CROC	-0 090	0	2	STE ALPI	-0 340	0	2	PLE SCHR	0.0	0	2
POL COMM	0 0	0	2	POL STRI	0 0	0	2				

G.4 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.)

In Salix polaris-Dactylina beringica Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.	SPECIES	COV DIF.	DISTB	CONTR.
CER BEER	0 010	1	0	MIN BIFL	0 0	1	1	ANT MONO	0 090	1	1
ART ARCT	-0 210	1	1	PET FRIG	0 400	1	1	SENEC SP	0 010	1	0
SEN LUGE	0 140	1	0	DES CAES	6 020	1	0	TRS SPIC	6 020	1	0
EPI ANGU	0 290	1	0	SIB PROC	0 590	1	1	SAL BARC	0.010	1	0
SAL POLA	-28 960	1	1	SAL RETI	0 0	1	1	PEL RUFE	0.010	1	0
PELTI SP	2 750	1	0	MOSS SPP	50 500	1	0				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF	DISTB	CONTR
RHO INTE	-0 010	0	1	CAR PODO	-0 190	0	1	GEN GLAU	-0 010	0	1
POA ARCT	-0 850	0	1	LUZ ARCU	-0 040	0	1	LUZ PARV	-0 040	0	1
POL ACUT	0 010	0	1	ANE NARC	-0.190	0	1	RAN ESCH	-0 010	0	1
PED SUDE	-0 010	0	1	CET ISLA	-0 250	0	1	CET NIVA	-0 090	0	1
CET RICH	-0 040	0	1	CLA MITI	-0 540	0	1	CLA COCC	-0 250	0	1
CLA ECMO	-0 800	0	1	CLA GONE	-0 250	0	1	DAC BERI	-0 900	0	1
NEP ARCT	-0 090	0	1	NEP EXPA	-0 800	0	1	PEL APHT	-0 540	0	1
SOL CROC	-0 090	0	1	STE ALPI	-0 340	0	1	PLE SCHR	0 0	0	1
POL COMM	0 0	0	1	POL STRI	0 0	0	1	RHA CANE	0 0	0	1

H.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.) In *Betula glandulosa*-*Cladonia stellaris*-Moss Tundra (n=6)

SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-5 567	4	3	CER BEER	0 010	1	0	MIN BIFL	0 010	1	0
SAG INIE	0 050	2	0	SAG LINN	0 010	1	0	STELL SP	0 0	1	1
MOE LATE	0 290	1	0	ANT ISOI	0 305	2	0	ANT MONO	0 247	3	2
ART ARCT	-5 285	2	1	AST SIBI	0 010	1	0	ERI HUMI	0 750	1	0
PET FRIG	0 010	1	0	SEN LUGE	0 925	2	0	SEN YUKO	0 010	1	0
TARAX SP	0 010	1	0	TAR ALAS	0.075	2	0	RHO INIE	0 010	1	0
ORA CRAS	0 010	1	0	DRA PRAE	0 010	1	0	CAREX SP	10 500	1	0
CAR A ST	63 000	1	0	ERI ANGU	0 750	1	0	EMP NIGR	0 010	2	0
EQU ARVE	33 300	1	1	LEO DECU	0 010	1	0	LEO GROE	0 010	1	0
AGP VIOL	0 010	1	0	AGS SCAB	0 010	1	0	DES CAES	7 675	4	1
FES ALTA	3 600	1	1	POA ALPN	1 200	1	0	TRS SPIC	1 020	3	0
JUN BALT	3 040	1	0	LUZ PARV	0 750	1	0	AST ALPI	0 010	1	0
HED ALPI	0 190	1	0	EPILO SP	0 010	1	0	LYC ANNO	0 140	1	0
LYC SELA	0 010	1	0	EPI ANGU	0 530	4	1	EPI LATI	1 920	1	0
PYROL SP	0 010	1	D	ANE NARC	-0 380	1	1	ORY OCTO	0 010	1	0
SIB PROC	0 280	3	0	SAL ALAX	2 190	1	0	SAL BARR	0 440	1	0
SAL GLAU	0 700	1	0	SAL LANA	0 700	1	0	SAL PLAN	-1 922	4	1
SAL A XP	0 010	2	0	SAL RETI	-0 023	4	1	PAR KOTZ	0 010	1	0
PEO SUDE	0 010	1	0	VER WORM	0 140	1	0	MIS LICH	1 100	2	0
CET CUCU	-0 660	1	1	CET PINA	-0 110	1	1	CET TILE	0 140	1	0
CLA CARI	0 0	1	0	CLA COCC	0 0	1	1	PAN PEZI	0 0	1	0
PEL APHT	0 040	1	0	PEL CANI	0 080	2	1	SOL CROC	0 010	1	0
STE ALPI	3 050	1	0	STE PASC	-1 680	1	1	BUE PAPI	0 0	1	0
MOSS SPP	5 904	5	5	BRA SALE	0 0	1	0	POG URNI	0 0	1	0
POL JUNI	0 0	1	1	POL PILI	0 0	1	1	TUR NORV	0 0	1	0

------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	9 840	0	1	MER PANI	-0 250	0	1	SIL ACAU	-0 010	0	1
ARN ALPI	0 190	0	1	SENEC SP	-1 100	0	1	SEN LUGE	-0 010	0	1
JUN COMM	-0 010	0	1	CAR PODO	-0 140	0	1	CAR SCIR	-0 140	0	1
EMP NIGR	2 405	0	2	ARC ALPI	-4 340	0	1	ARC UVA-	-2 800	0	1
LED GROE	-4 950	0	1	VAC ULIG	-7 050	0	1	VAC VITI	0 388	0	5
GEN GLAU	0 140	0	1	GRAMINEA	12 500	0	1	FES ALTA	-1 560	0	1
HED ALPI	0 010	0	1	LYC ALPI	0 010	0	1	LYC CLAV	-0 010	0	1
EPI ANGU	-1 200	0	1	POL ACUI	-0 725	0	2	POL VIVI	0 010	0	2
ANE NARC	-0 010	0	1	ANE PARV	-0 010	0	1	THA ALPI	-0 140	0	1
ORY INFF	-0 750	0	1	POT FRUT	-0 010	0	1	RUB ACAU	-0 010	0	1
SAL GLAU	0 010	0	1	SAL RETI	-0 010	0	1	PEDIC SP	-1 100	0	1
PED LABR	0 010	0	1	VAL CAPI	-1 200	0	1	CET CUCU	-0 040	0	1
CET ISLA	-2 072	0	5	CET LAEV	-0 250	0	1	CET NIVA	-0 920	0	3
CET PINA	-0 135	0	4	CET RICH	-0 647	0	4	CLA ARBU	-8 165	0	2
CLA MITI	-12 040	0	2	CLA RANG	-1 662	0	4	CLA STEL	-44 167	0	3
CLA BELL	0 0	0	1	CLA CARN	0 0	0	2	CLA CENO	0 0	0	1
CLA COCC	0 0	0	2	CLA CORN	-1.310	0	1	CLA CRIS	0 0	0	1
CLA DEFO	0 0	0	1	CLA GONE	0 0	0	4	CLA G OI	-1 310	0	1
CLA G GR	0 0	0	2	CLA MACA	0 0	0	1	CLA PLEU	0 0	0	1
CLA POCI	-0 700	0	1	CLA SUBU	-0 250	0	1	CLA VERT	0 0	0	1
CLAD SPP	0 355	0	4	DAC BERI	-0 850	0	1	NEP ARCT	-0 010	0	2
PAR AMBI	-0 220	0	2	PAR HYPE	-0 250	0	1	PEL APHT	-0 670	0	3
SOL CROC	-0 190	0	1	STE PASC	-3 715	0	2	MOSS SPP	-12 450	0	1
HYL SPLE	0 0	0	2	PLE SCHR	0 0	0	2	POL COMM	0 0	0	1
POL JUNI	0 0	0	1	POL STRI	0 0	0	3				

H.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.) In *Betula glandulosa*-*Cladonia stellaris*-Moss Tundra (n=8)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-13 491	7	6	MER PANI	0 010	1	0	STELL SP	0 025	2	0
ANTEN SP	0 010	1	0	ANT ISOL	0 010	1	0	ANT MONO	1 186	5	1
ANT STOL	0 010	1	0	ART ARCT	0 010	1	0	ART TILE	0 010	1	0
AST SIBI	0 010	1	0	PET FRIG	-0 365	2	1	PET HYPE	0 010	1	0
SEN LUGE	0 480	2	0	SEN TRIA	0 010	1	0	SOL MULT	0 010	2	0
RHO INIE	0 025	2	0	CAR A ST	19 375	2	0	CAR AURE	1 525	2	0
CAR BRUN	-0 040	3	2	CAR CAPI	3 040	1	0	CAR DEFL	0 010	1	0
CAR MEMB	20 500	1	0	EMP NIGR	0 424	5	1	EQU ARVE	0.360	1	1
CAS TETR	0 005	4	2	KAL P MI	0 090	1	0	KAL P PD	0 010	1	0
LEO OECU	0 010	1	0	LEO GROE	0.010	3	0	PHY EMPT	0.010	3	0
VAC ULIG	0.015	4	1	VAC VITI	-0 035	2	1	GEN GLAU	0.380	2	0
GEN PROP	0 010	1	0	AGS SCAB	0 075	2	0	CAL CANA	-1.020	2	1
DES CAES	2 260	4	1	FES ALTA	10 865	4	1	MIE ALPI	0 010	1	0
POA ALPG	1 660	1	0	POA ALPN	10 500	1	0	TRS SPIC	0 017	4	0
JUN BALT	0 010	1	0	JUN ALBE	0 010	1	0	LUZ PARV	0 717	3	1
HEO ALPI	0 010	1	0	LYC ALPI	0 010	3	0	LYC ANNO	0 010	2	0
LYC CLAV	0 010	3	0	LYC SELA	0 010	3	0	EPI ANGU	0 536	7	3
EPI LATI	0 010	3	0	BOT LUNA	0 040	1	0	PIC GLAU	0.010	1	0
POL ACUI	-1 070	2	2	POL VIVI	0 010	1	0	PYROL SP	0.010	1	0
PYR MINO	0 010	1	0	ANE PARV	0.010	2	0	THA ALPI	0.010	1	0
ABI LASI	0 010	1	0	POT FRUI	0 010	1	0	RUB ACAU	0 010	3	3
RUB CHAM	0 010	2	0	SIB PROC	0 220	6	2	SPI BEAU	0 007	3	1
POP BALS	0 010	2	0	SAL ALAX	0 737	3	D	SAL BARR	0.010	1	0
SAL GLAU	0 010	3	0	SAL MYRT	0 010	2	0	SAL PLAN	4.884	7	3
SAL POLA	0 090	1	0	SAL RETI	-1 175	2	2	PAR KOTZ	0 200	2	0
PEO LABR	0 010	2	0	PED SUDE	0 010	1	0	VER WORM	0.025	2	0
VAL CAPI	-1 190	2	2	BAC ALPI	0 010	1	0	BAE RUFU	0 005	2	0
CET CUCU	-0 180	2	2	CET ISLA	0 007	4	4	CET LAEV	0 395	2	0
CET NIVA	-4 892	4	2	CET PINA	-0 512	5	5	CET RICH	-0 030	1	1
CET TILE	0 250	1	0	CLA ARBU	0 010	1	0	CLA MITI	-52 250	1	1
CLA RANG	-2 965	2	2	CLA STEL	-20 206	5	4	CLADO SP	0 250	1	0
CLA ACUM	0 0	1	0	CLA CARI	0 0	1	0	CLA CARN	0.083	3	3
CLA CHLO	0 0	1	0	CLA COCC	0 085	4	3	CLA CORN	-0 080	3	2
CLA GONE	0 0	1	1	CLA G OI	0 0	2	1	CLA G GR	0 010	1	1
CLA MACA	0 040	1	0	CLA MAJO	0 010	1	0	CLA META	0.0	1	0
CLA PLEU	0 005	2	1	CLA POCI	0.125	2	0	CLA PYXI	0 010	1	0
CLA SUBU	0 0	1	0	CLA UNCI	0.315	2	1	CLAD SPP	12 167	3	1
NEP ARCT	0 0	3	3	STER SPP	2 580	1	0	PAN PEZI	0.010	1	0
PEL APHT	0 250	7	6	PEL CANI	4 800	1	0	PEL MALA	0.010	1	0
PEL PULV	0 070	2	1	PEL RUFE	3.360	2	0	PEL SPUR	0.115	3	0
SOL CROC	0 268	6	4	STE ALPI	1.185	4	0	STE PASC	1.660	1	0
STE RIVU	0 0	1	0	STE SAXA	3.360	1	0	STE TOME	0.325	2	0
TON LOBU	1 210	1	0	CRUSTOSE	9 050	1	0	SOIL LIC	2 922	4	1
SAX LICH	1 460	2	0	RHIZO SP	0 0	1	0	NAME	D.010	1	0
LEC STIG	0 540	1	0	LECIDEA	0 0	1	0	STERE SP	0 0	1	0
HEPATICS	0 010	1	1	MOSS SPP	9.510	5	4	POLYI SP	0 D	1	0
POLY SPP	41 000	1	0	AUL PALU	0 005	2	0	BRYUM SP	0 005	3	0
CAM S AR	0 0	1	0	CAM S'EL	0.0	1	0	CER PURP	0.0	2	1
DIT FLEX	0 0	1	0	DRL REVO	0 0	1	0	ORE UNCI	0 010	1	0
HYL SPLE	0 0	2	0	HYP BAMB	0 0	1	0	PLE SCHR	D 005	2	2
POL COMM	-0 325	2	2	POL HYPE	0 003	3	0	POL JUNI	5 324	5	1
POL PILI	15 872	5	0	RHA CANE	0 003	3	0				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.	SPECIES	COV DIF	DISTB.	CONTR.
ART ARCT	-0 010	0	1	SENEC SP	-1 100	0	2	EQU ARVE	-1.200	0	1
VAC VITI	-0 222	0	5	GEN GLAU	-0 010	0	1	GRAMINEA	-12.500	0	2
LYC ALPI	-0 010	0	1	RUB CHAM	-0 010	0	1	PEDIC SP	-1 100	0	2
ALE OCHR	-0.010	0	1	CET CUCU	-0 495	0	2	CET ISLA	-3 865	0	2
CET NIVA	-0.140	0	2	CET PINA	-0 250	0	1	CET RICH	-0.165	0	4
CET SEPI	-1 920	0	1	CLA ARBU	-0 010	0	1	CLA MITI	-52 500	0	1
CLA RANG	-7 658	0	4	CLA STEL	-26 930	0	2	CLA AMAU	-1 100	0	1
CLA BELL	-0 010	0	1	CLA CARN	-0 010	0	1	CLA CENO	0 0	0	1
CLA COCC	-1 400	0	2	CLA CRIS	0.0	0	3	CLA DEFD	-D 005	0	4
CLA FIMB	-0 003	0	3	CLA GONE	-0 220	0	3	CLA G GR	-4 850	0	1
CLA MACA	0 0	0	1	CLA MAJO	-0 010	0	1	CLA SUBF	-0 010	0	4
CLA SUBU	-0 040	0	2	CLA UNCI	0 0	0	1	CLAD SPP	-0.393	0	3
DAC ARCT	-0.010	0	1	ICM ERIC	-0 010	0	1	LEC GRAN	-0.075	0	2
DCH ANDR	-0 140	0	1	PAR SEPT	-0 190	0	1	PAR AMBI	-0 230	0	3
PAR HYPE	0 807	0	3	PEL APHT	-1 100	0	1	PEL CANI	-0 010	0	1
STE ALPI	0 010	0	1	STE PASC	2 878	0	5	UMB HYPE	-0 010	0	1
UMB PROB	0 010	0	1	HEPATICS	0 0	0	1	MOSS SPP	-0 340	0	1
AUL PALU	8 020	0	2	DICRANUM	0 010	0	1	ORE UNCI	-0 010	0	1
HYL SPLE	-0 010	0	1	PLE SCHR	0 0	0	2	POL COMM	-14 007	0	3
POL JUNI	3 040	0	1	POL PILI	-0 010	0	1	POL STRI	-0 577	0	4

H.3 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.) In Betula glandulosa-Cladonia stellaris-Moss Tundra (n=6)

SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-16.577	4	4	STE EDWA	0.010	1	0	ANT ISOL	0.010	1	0
ANT MUNO	-0.690	1	1	ART ARCT	-5.285	2	1	PET FRIG	-0.740	1	1
CAR BRUN	0.010	1	0	CAR PHAE	0.600	1	0	CAR PUDO	-0.130	1	1
EMP NIGR	0.015	2	2	CAS TETR	0.010	1	0	VAC ULIG	0.010	1	0
VAC VITI	0.595	6	6	GEN GLAU	-0.037	3	1	AGS SCAB	0.140	1	0
CAL CANA	2.700	1	0	CAL LAPP	0.010	1	0	FES ALTA	-0.760	6	2
HIE ALPI	0.440	1	0	LUZ PARV	0.0	1	1	LYC ALPI	0.0	1	1
LYC CLAV	0.007	3	1	EPI ANGU	0.770	4	1	EPI LATI	0.010	1	0
POL ACUT	-0.240	1	1	POL VIVI	0.0	1	1	ANE NARC	-0.380	1	1
RAN ESCH	0.010	1	0	RUB ACAU	0.0	1	1	RUB CHAM	0.010	1	0
SIB PROC	0.0	1	1	SPI BEAU	0.010	1	0	SAL PLAN	-3.530	4	3
BASIDIOM	0.065	2	0	ALE OCHR	0.0	1	1	CET CUCU	-0.015	4	2
CET ERIC	0.010	1	0	CET ISLA	0.557	6	6	CET NIVA	-2.188	6	6
CET PINA	-0.080	1	1	CET RICH	-0.138	5	5	CET TILE	0.250	1	0
CLA AMAU	-0.605	2	1	CLA MITI	-6.697	3	2	CLA RANG	-1.350	4	4
CLA STEL	-22.610	4	4	CLA BACF	1.360	1	0	CLA CARN	0.0	1	0
CLA CENO	0.0	1	0	CLA COCC	-0.360	4	3	CLA CORN	1.080	3	1
CLA CRIS	0.425	4	2	CLA DEFO	0.673	3	2	CLA FURC	0.0	1	0
CLA GUNE	0.272	5	4	CLA G DI	-0.440	3	2	CLA G GR	-1.350	3	2
CLA MACA	1.470	3	1	CLA PLEU	0.0	3	0	CLA SUBU	-0.240	1	1
CLA UNCI	0.010	1	0	CLAD SPP	1.500	5	3	DAC ARCT	0.010	1	0
DAC BERI	-0.840	1	1	LEC GRAN	0.790	1	1	NEP ARCT	0.0	2	2
PEL APHT	-0.450	2	2	PEL MALA	0.145	2	0	PEL POLY	0.010	1	0
PEL PULV	0.090	2	1	PSO HYPN	0.010	1	0	SOL CRUC	1.737	3	2
STE PASC	3.304	5	5	STE TOME	0.340	1	0	CRUSTOSE	0.250	1	0
SOIL LIC	0.295	2	0	PELT SPP	1.970	1	0	BUE DISC	0.0	1	0
DACTYLIN	0.140	1	0	HEPATICS	0.0	2	2	MOSS SPP	3.184	5	4
POLYT SP	27.167	3	0	AUL PALU	0.0	1	1	BRYACEAE	0.0	1	0
DICRANUM	-0.010	1	1	DIT FLEX	0.0	1	0	DRE UNCI	0.0	1	0
HYL SPLE	0.0	1	0	PLE SCHR	0.0	2	2	POL COMM	-21.005	2	2
POL JUNI	-1.013	3	1	POL PILI	0.0	1	0	POL STRI	17.165	4	3

------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-12.500	0	1	STELL SP	-0.010	0	1	CAR BRUN	-0.090	0	1
CAS TETR	-0.010	0	1	CAL CANA	-3.510	0	1	EPI ANGU	-0.010	0	1
CET CUCU	-0.040	0	1	CET PINA	0.244	0	5	CET RICH	-0.700	0	1
CLA ARBU	0.010	0	1	CLA MITI	-52.500	0	1	CLA RANG	0.610	0	2
CLA STEL	-13.000	0	1	CLA BELL	-0.005	0	2	CLA CARN	-0.007	0	3
CLA COCC	0.0	0	1	CLA CORN	-1.310	0	1	CLA DEFU	-0.010	0	1
CLA FIMB	-0.010	0	1	CLA GONE	0.0	0	1	CLA G GR	0.0	0	1
CLA PLEU	0.0	0	1	CLA SUBF	-0.010	0	2	CLA SUBU	-0.040	0	1
CLA UNCI	-0.010	0	1	CLA VERT	0.0	0	1	CLAD SPP	-0.040	0	1
ICM ERIC	-0.010	0	1	LEC GRAN	-0.140	0	1	OCH ANDR	-0.140	0	1
PAR SEPT	-0.190	0	1	PAR AMBI	0.220	0	4	PAR HYPE	0.250	0	1
PEL APHT	-0.010	0	2	SOL CROC	-0.010	0	2	STE ALPI	0.010	0	1
STE PASC	-3.920	0	1	UMB HYPE	0.010	0	1	UMB PROB	-0.010	0	1
SOIL LIC	-0.653	0	1	CER PURP	-0.010	0	1	DRE UNCI	-0.010	0	1
HYL SPLE	0.005	0	2	PLE SCHR	0.0	0	1	POL COMM	-0.005	0	2
POL JUNI	0.0	0	1	POL PILI	0.0	0	1	POL STRI	0.0	0	1

H.4 Cover Differences (Cov.Dif.) Between Camp Yards (Distb.) and Their Controls (Contr.) In Betula glandulosa-Cladonia stellaris-Moss Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR
BET GLAN	-12.870	1	1	STE MUNA	0.010	1	0	CHE CAPI	0.010	1	0
ANT ISOL	0.010	1	0	CAR PHAE	0.010	1	0	EMP NIGR	7.590	1	0
GEN GLAU	0.010	1	0	AGP VIOL	0.010	1	0	AGS SCAB	0.075	2	0
CAL CANA	0.010	1	0	FES ALTA	2.250	1	0	HOR JUBA	0.010	1	0
PHL COMM	0.010	1	0	POA GLAU	0.010	1	0	TRS SPIC	0.190	1	0
LYC ALPI	0.010	1	0	LYC CLAV	0.040	1	0	EPI ANGU	3.000	1	0
BOT LUNA	0.010	1	0	POT NURV	0.010	1	0	SIB PROC	0.010	1	0
SAL ALAK	0.010	1	0	SAL PLAN	0.140	1	0	CET CUCU	0.150	1	1
CET ISLA	0.0	1	1	CET NIVA	-0.050	1	1	CET PINA	0.0	1	1
CLA MITI	-52.310	1	1	CLA BOTR	0.010	1	0	CLA COCC	0.540	1	1
CLA G DI	0.800	1	0	CLA G GR	0.800	1	0	CLA PLEU	0.010	1	0
CLA UNCI	0.190	1	0	CLA VERI	0.090	1	0	PEL APHT	4.740	1	1
PSO HYPN	0.010	1	0	SOL CRUC	0.0	1	1	STE TOME	1.660	1	0
MOSS SPP	0.600	1	0	POLYT SP	70.500	1	0	BRYUM SP	0.0	1	0
CER PURP	0.0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.
CAR BRUN	-0.090	0	1	VAC VITI	-0.040	0	1	CET RICH	-0.040	0	1
CLA RANG	-3.050	0	1	CLA STEL	-1.360	0	1	CLA CRIS	0.0	0	1
CLA DEFO	0.0	0	1	CLA SUUF	-0.010	0	1	CLA SUBU	0.040	0	1
CLAD SPP	-0.040	0	1	PAR AMBI	-0.250	0	1	STE PASC	-0.290	0	1
POL COMM	-0.010	0	1								

H.5 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Betula glandulosa-Cladonia stellaris-Moss Tundra (n=16)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR
BET GLAN	-13.107	12	10	MER PANI	-0.073	3	1	LIN BORE	0.010	1	0
CER BEER	0.010	1	0	MIN BIFL	0.010	1	0	MIN R EL	0.010	1	0
MIN STRI	0.010	2	0	SAG LINN	0.010	1	0	SIL ACAU	0.010	2	0
STE LAET	0.010	1	0	ANTEN SP	0.010	3	0	ANT EKMA	0.010	2	0
ANT ISOL	0.040	1	0	ANT MONO	-0.264	5	2	ARN ALPI	-0.180	1	1
ARN LESS	0.010	1	0	ART ARCT	-4.080	5	3	AST SIBI	0.017	3	0
CRE NANA	0.010	1	0	ERIGE SP	0.010	1	0	HIE TRIS	0.100	2	0
PET FRIG	0.010	3	0	SEN LUGE	0.454	5	1	SEN CYMB	0.010	1	0
SOL MULT	0.010	3	0	TARAX SP	0.010	1	0	TAR ALAS	0.010	3	0
RHO INTE	0.010	2	0	JUN COMM	0.960	2	1	CAR ATSO	3.040	1	0
CAR AURE	0.010	1	0	CAR BRUN	-0.020	2	1	CAR DEFL	0.010	1	0
CAR MEMB	18.500	1	0	CAR PETR	0.010	1	0	CAR PHAE	0.010	1	0
CAR POUO	-0.083	3	2	CAR SCIR	-0.037	3	1	ERI SCHE	1.920	1	0
SHE CANA	0.010	4	0	EMP NIGR	0.006	5	2	EQU ARVE	-0.590	2	1
EQU SCIR	0.010	2	0	EQU VARI	20.500	1	0	ARC ALPI	-0.300	4	1
CAS TETR	0.003	3	2	LED DECU	0.010	2	0	LED GROE	-1.640	3	1
PHY EMPT	0.010	1	0	VAC ULIG	-0.999	7	2	VAC VITI	-0.377	7	7
GEN GLAU	0.005	2	1	GEN PRUS	0.010	1	0	GEN PRUP	0.010	2	0
GRAMINEA	-12.490	1	1	AGP VIUL	0.010	1	0	AGS SCAB	0.010	2	0
ARC LATI	0.010	2	0	CAL CANA	0.010	2	0	CAL LAPP	0.010	3	0
CAL PURP	0.010	1	0	DES CAES	0.564	5	1	FES ALTA	0.252	6	3
HIE ALPI	0.025	2	0	POA ALPG	0.010	1	0	POA ALPN	0.555	2	0
POA ARCT	0.010	1	0	POA GLAU	0.010	1	0	IRS SPIC	0.120	6	0
JUN BALT	1.920	1	0	JUN CAST	0.010	1	0	LUZ ARCU	0.010	2	0
LUZ NIVA	0.010	1	0	LUZ PARV	-0.390	3	2	AST ALPI	0.010	1	0
HEO ALPI	1.534	5	1	EPILO SP	0.010	2	0	OXY DEFL	0.075	2	0
LLO SERO	0.010	1	0	LYC ALPI	0.007	3	1	LYC ANNO	0.010	1	0
LYC CLAV	0.010	5	0	LYC SELA	0.010	1	0	EPI ANAG	0.010	1	0
EPI ANGU	0.118	12	3	EPI LATI	0.428	9	0	BUT LUNA	0.020	3	0
POL ACUT	-0.240	1	1	POL VIVI	0.010	1	0	RUM ARCT	0.010	1	0
RUM OCCI	0.010	1	0	AND CHAM	0.010	1	0	PYRUL SP	0.010	1	0
PYR ASAR	0.010	1	0	PYR GRAN	0.010	2	0	PYR SECU	0.010	1	0
ANE NARC	0.0	1	1	ANE PARV	0.008	4	1	THA ALPI	-0.060	2	1
DRY INTE	2.723	3	0	DRY OCTO	0.010	1	0	DRY SYLV	0.190	1	0
GEU ROSS	0.010	1	0	POT FRUT	0.008	4	1	RUB ACAU	0.010	1	0
SIB PROC	0.006	8	3	SPI BEAU	0.007	3	1	POP BALS	0.010	6	0
SAL ALAX	1.552	9	0	SAL ARCT	0.010	1	0	SAL OODG	0.190	1	0
SAL GLAU	0.614	5	1	SAL MYRT	0.040	1	0	SAL PLAN	0.906	9	5
SAL POLA	0.010	1	0	SAL A XP	0.010	2	0	SAL RETI	-0.230	5	1
SAL SPP	1.200	1	0	PAR KOTZ	0.010	2	0	SAX AIZO	0.010	2	0
SAX OPPU	0.010	1	0	SAX TRIC	0.010	1	0	PEO SUDE	0.010	1	0
VER WORM	0.010	1	0	ALE OCHR	0.080	1	1	BAE RUSE	0.610	2	0
BAE RUFU	0.0	1	0	CET CUCU	-0.155	8	6	CET OLLI	0.395	2	0
CET ERIC	0.025	2	0	CET ISLA	-1.330	6	6	CET NIVA	0.103	6	5
CET PINA	-0.326	7	7	CET RICH	-0.015	2	2	CET TILE	0.010	1	0
CLA STEL	-18.512	5	5	CLADO SP	0.610	2	0	CLA ACUM	0.0	1	0
CLA CARI	0.007	3	0	CLA CARN	0.300	2	1	CLA CHLO	0.0	1	0
CLA CUCC	-0.295	6	4	CLA CORN	-0.230	3	2	CLA DEFO	-0.005	2	2
CLA FIMB	-0.005	2	2	CLA GONE	0.010	1	1	CLA G OI	-0.003	3	2
CLA G GR	-1.202	4	2	CLA MACA	0.010	1	0	CLA MACR	0.0	1	0
CLA PLEU	0.010	1	0	CLA PUCI	0.300	2	0	CLA PYXI	0.010	1	0
CLA SUBU	0.257	3	1	CLA UNCI	0.005	2	1	CLA VERT	0.0	1	0
CLAD SPP	2.265	2	1	NEP ARCT	0.0	2	2	STER SPP	24.500	2	0
OMP VIRG	0.010	1	0	PAN PEZI	2.355	2	0	PEL APHT	0.011	7	5
PEL CANI	0.528	6	0	PEL MALA	0.107	3	0	PEL RUFE	0.007	3	0
PEL VENO	0.010	1	0	POL SENU	0.0	1	0	PSO HYPN	4.500	2	0
SOL CROC	1.329	8	5	STE ALPI	0.185	4	0	STE CONU	0.0	1	0
STE GLAR	0.005	2	0	STE PASC	-1.600	3	3	STE SAXA	0.0	1	0
STE TUME	0.770	7	0	ION LOBU	4.500	2	0	UMB HYPE	0.010	1	0
UMB PRUB	0.010	1	0	SOIL LIC	8.400	2	0	SAX LICH	0.820	2	0
RHIZO SP	0.0	1	0	COLLEMA	5.150	1	0	LEC JURA	0.083	3	0
LEC GLAU	0.0	1	0	LEC CRUS	0.0	1	0	LEC LIMO	0.0	1	0
HEPATICS	0.010	2	1	MOSS SPP	-3.017	11	9	POLYT SP	2.167	3	0
AUL PALU	0.010	2	1	BRA SALE	0.010	1	0	BRYACEAE	0.010	1	0
BRYUM SP	0.010	2	0	CAL STRA	0.010	1	0	CER PURP	0.010	2	0
DRE UNCI	0.010	2	0	DIC VIRE	0.010	2	0	POL COMM	-20.085	2	2
POL HYPE	0.0	1	0	POL JUNI	0.720	6	2	POL PILI	2.260	5	1
POL STRI	0.0	1	1	RHA CANE	0.0	4	0	PHI FONT	0.010	1	0
POG OINT	0.010	1	0								

H.5 continued

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-15.010	0	1	SIL ACAU	-0.010	0	1	STELL SP	-0.010	0	2
ANT MONO	-0.250	0	1	PET FRIG	-0.750	0	2	SENEC SP	-1.100	0	3
CAR BRUN	-0.090	0	3	EMP NIGR	-1.607	0	3	EQU ARVE	-1.200	0	2
ARC HVA-	-2.800	0	1	CAS TETR	-0.010	0	1	VAC VITI	-0.289	0	7
GEN GLAU	-0.140	0	2	GRAMINEA	-12.500	0	2	CAL CANA	-3.510	0	2
FES ALTA	-6.900	0	2	LYC ALPI	-0.010	0	2	LYC CLAV	-0.010	0	2
EPI ANGU	-1.200	0	3	POL ACUT	-0.962	0	4	POL VIVI	-0.010	0	3
ANE NARC	-0.390	0	2	DRY INTE	-0.750	0	1	RUB ACAU	-0.010	0	5
RUB CHAM	-0.010	0	1	SAL PLAN	-13.790	0	1	SAL RETI	-0.803	0	3
PEDIC SP	-1.100	0	3	PED LABR	-0.010	0	1	VAL CAPI	-1.200	0	3
CET CUCU	-0.040	0	2	CET ISLA	-0.707	0	7	CET LAEV	-0.250	0	1
CET NIVA	-4.084	0	5	CET PINA	-0.157	0	6	CET RICH	-0.255	0	10
CET SEPI	-1.920	0	1	CLA ARBU	-3.550	0	5	CLA MITI	-36.511	0	7
CLA RANG	-4.102	0	12	CLA STEL	-19.944	0	5	CLA AMAU	-1.100	0	1
CLA BELL	-0.007	0	3	CLA CARN	-0.006	0	5	CLA CENO	0.0	0	1
CLA COCC	0.0	0	4	CLA CORN	-0.655	0	2	CLA CRIS	0.0	0	6
CLA DEFO	-0.002	0	6	CLA FIMB	0.0	0	2	CLA GONE	-0.096	0	7
CLA G OI	-1.310	0	1	CLA G GR	0.0	0	2	CLA MACA	0.0	0	2
CLA MAJO	-0.010	0	1	CLA PLEU	0.0	0	3	CLA POCI	-0.700	0	1
CLA SUBF	-0.010	0	6	CLA SUBU	-0.124	0	5	CLA UNCI	-0.005	0	2
CLA VERT	0.0	0	1	CLAD SPP	-0.292	0	8	DAC ARCT	-0.010	0	1
DAC BERI	-0.850	0	2	ICM ERIC	-0.010	0	1	LEC GRAN	-0.053	0	3
NEP ARCT	-0.010	0	4	OCH ANDR	-0.140	0	1	PAR SEPT	-0.190	0	1
PAR AMBI	-0.240	0	6	PAR HYPE	-0.668	0	4	PEL APHT	-0.530	0	8
PEL CANI	-0.025	0	2	PEL PULV	-0.010	0	2	SOL CROC	-0.100	0	4
STE ALPI	-0.010	0	1	STE PASC	-2.712	0	8	UMB HYPE	-0.010	0	1
UMB PRUB	-0.010	0	1	SOIL LIC	-0.650	0	1	HEPATICS	0.0	0	2
MOSS SPP	-11.450	0	2	AUL PALU	-8.020	0	2	CER PURP	-0.010	0	1
DICRANUM	-0.010	0	1	DRE UNCI	-0.010	0	1	HYL SPLE	-0.003	0	3
PLE SCHR	0.0	0	6	POL COMM	-5.256	0	8	POL JUNI	-3.040	0	1
PUL PILI	0.0	0	1	POL STRI	-0.330	0	7				

H.6 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.)

In Betula glandulosa-Cladonia stellaris-Moss Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB.	CONTR.	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-19.750	1	1	ANT MONO	0.010	1	0	ANT STOL	3.920	1	0
HIE TRIS	0.010	1	0	CAR BRUN	0.010	1	0	CAR PODD	0.010	1	0
EMP NIGR	0.010	1	0	CAS TETR	0.600	1	0	VAC ULIG	0.750	1	0
VAC VITI	-0.080	1	1	GEN GLAU	0.600	1	0	CAL CANA	0.010	1	0
DES CAES	1.210	1	0	FES ALTA	3.360	1	0	LUZ ARCU	1.920	1	0
LUZ MULT	0.040	1	0	EPI ANGU	0.0	1	1	SIB PROC	1.100	1	0
SPI BEAU	0.040	1	0	SAL PLAN	4.350	1	1	CET ISLA	2.540	1	1
CET NIVA	-19.490	1	1	CET PINA	-0.050	1	1	CLA RANG	-2.710	1	1
CLA STEL	-30.960	1	1	CLA BACL	0.0	1	0	CLA BELL	0.0	1	0
CLA CARN	-0.010	1	1	CLA CHLO	0.0	1	0	CLA COCC	-2.800	1	1
CLA G OI	0.010	1	0	CLA G GR	-3.850	1	1	CLA LEPI	0.010	1	0
CLAD SPP	0.250	1	0	PEL APHT	0.280	1	1	PEL PULV	0.290	1	0
SOL CROC	11.500	1	1	STE CONO	0.750	1	0	STE PASC	20.050	1	1
OCH INAE	1.260	1	0	LECIDEA	0.750	1	0	HEPATICS	0.010	2	2
MOSS SPP	1.560	1	0	DRE UNCI	0.0	1	1	PLE SCHR	0.0	1	1
POL COMM	16.490	1	1	POL PILI	16.500	1	0	RHA CANE	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF	DISTB	CONTR	SPECIES	COV.DIF.	DISTB	CONTR
ALE OCHR	-0.010	0	1	CET CUCU	-0.340	0	1	CET RICH	-0.010	0	1
CLA GONE	-0.650	0	1	CLA SUBF	-0.010	0	1	ICM ERIC	-0.010	0	1
LEC GRAN	-0.140	0	1	OCH ANDR	-0.140	0	1	PAR SEPT	-0.190	0	1
PAR AMBI	-0.190	0	1	STE ALPI	-0.010	0	1	UMB HYPE	-0.010	0	1
UMB PROB	-0.010	0	1	SOIL LIC	-0.650	0	1	CER PURP	-0.010	0	1
DICRANUM	0.010	0	1	HYL SPLE	-0.010	0	1	POL JUNI	-3.040	0	1
POL STRI	-1.660	0	1								

H.7 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.)

In Betola glandulosa-Cladonia stellaris-Moss Tundra (n=8)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-15.747	3	3	ART ARCT	0.010	1	0	CAREX SP	0.040	1	0
CAR BRUN	0.0	1	1	CAR LACH	0.010	1	0	CAR PODO	0.010	1	0
EMP NIGR	0.010	1	0	EQU SCIR	0.010	1	0	VAC VITI	-0.267	4	4
GRAMINEA	0.190	1	0	CAL CANA	-3.500	1	1	FES ALTA	0.010	1	0
POA ALPN	0.010	1	0	TRS SPIC	0.010	1	0	LOZ PARV	0.255	2	1
LYC SELA	0.010	1	0	EPI ANGU	1.990	2	0	POL ACUT	0.010	1	0
POT DIVE	0.010	1	0	RUB ACAU	0.005	2	1	SALIX SP	0.010	1	0
SAL GLAU	0.010	1	0	SAL PLAN	3.040	1	0	SAL A XP	0.010	1	0
SAL RETI	0.010	1	0	VER WORM	0.010	1	0	MIS LICH	23.878	5	0
CET ISLA	-0.005	2	2	CET NIVA	-0.657	3	2	CET RICH	-0.590	1	1
CLA RANG	-3.050	1	1	CLA STEL	-8.053	3	3	CLA BACF	0.145	2	0
CLA BOTR	0.010	1	0	CLA CARN	0.0	1	0	CLA COCC	0.005	2	1
CLA DECO	0.0	1	0	CLA GONE	0.005	2	2	CLA G DI	0.005	2	0
CLA PLEU	0.010	1	0	CLA PUCI	0.0	1	0	CLA PYXI	0.0	1	0
CLA VERT	0.0	1	0	CLAD SPP	0.200	1	1	LEC GRAN	0.010	1	0
PAN PEZI	0.0	1	0	PEL APHT	0.0	1	0	STE ALPI	0.0	2	0
STE PASC	-0.177	3	3	TON IRIS	0.010	1	0	CLADINA	19.400	1	0
MOSS SPP	7.920	4	2	POLYT SP	22.250	2	0	AUL PALU	0.0	1	0
POL COMM	-41.990	1	1	POL HYPE	0.0	1	0	POL JUNI	0.003	7	0
POL PILI	0.0	3	0	POL STRT	-0.320	2	1				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-16.308	0	5	ART ARCT	-0.010	0	1	PET FRIG	-0.750	0	1
CAR BRUN	0.090	0	3	EMP NIGR	-0.010	0	1	CAS TETR	0.010	0	2
VAC OLIG	-0.010	0	1	VAC VITI	-0.077	0	4	GEN GLAU	-0.010	0	1
FES ALTA	-0.010	0	1	LYC ALPI	-0.010	0	1	RUB CHAM	-0.010	0	1
SIB PROC	-0.010	0	2	SPI BEAU	-0.010	0	1	SAL PLAN	0.010	0	2
CET CUCU	0.222	0	5	CET ISLA	0.042	0	6	CET NIVA	0.516	0	5
CET PINA	-0.467	0	8	CET RICH	-0.441	0	7	CET SEPI	-1.920	0	1
CLA ARBU	-0.010	0	1	CLA MITI	-52.500	0	4	CLA RANG	5.077	0	7
CLA STEL	-36.744	0	5	CLA AMAU	-1.100	0	1	CLA BELL	-0.010	0	1
CLA CARN	-0.005	0	2	CLA COCC	-0.002	0	6	CLA CORN	-0.375	0	2
CLA CRIS	0.0	0	5	CLA DEFO	-0.003	0	6	CLA FIMB	-0.003	0	3
CLA GONE	-0.005	0	2	CLA G DI	-0.010	0	1	CLA G GR	0.0	0	3
CLA MACA	0.0	0	1	CLA MAJO	-0.010	0	1	CLA PLEU	0.0	0	1
CLA SUBF	-0.010	0	5	CLA SUBO	-0.040	0	4	CLA ONCI	-0.005	0	2
CLAD SPP	-0.192	0	6	DAC ARCT	-0.010	0	1	LEC GRAN	-0.010	0	1
NEP ARCT	-0.010	0	2	PAR AMBI	-0.230	0	6	PAR HYPE	-1.085	0	2
PEL APHT	-0.010	0	5	PEL CANI	-0.010	0	1	PEL PULV	-0.010	0	1
SOL CROC	-0.010	0	5	STE PASC	-2.254	0	5	HEPATICS	0.0	0	1
MOSS SPP	0.595	0	2	AUL PALU	-8.020	0	2	PTE SCHR	0.0	0	2
POL COMM	-0.138	0	5	POL PILT	-0.010	0	1	POL STRI	0.0	0	1

I.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Cladonia stellaris-Alectoria ochroleuca Tundra (n=6)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ALN CRIS	0.010	1	0	BET GLAN	-4.293	3	3	CER BEER	0.010	1	0
MIN ARCT	7.680	1	1	MIN MACR	4.385	4	0	MIN R EL	0.010	1	0
MIN RUBE	0.010	2	0	MIN STRI	0.010	1	0	SIL ACAU	0.260	2	1
STELL SP	0.010	1	0	STE LAET	0.010	1	0	ANT DENS	0.010	1	0
ANT EKMA	0.010	1	0	ANT MONO	0.010	1	0	ARN ALPI	0.010	2	0
ARN LOUI	0.010	1	0	ART ARCT	0.924	5	3	ART T EL	0.010	1	0
CRE NANA	0.010	1	0	ERI ERIO	0.010	1	0	ERI HYPE	0.010	1	0
ERI PURP	0.010	1	0	ERI HUMI	0.010	1	0	SOL MULT	0.010	1	0
TAR ALAS	0.010	1	0	CAR BELL	0.010	1	0	DRA CORY	0.010	1	0
DRA LACT	0.010	1	0	CAR GLAC	0.010	1	0	CAR MEMB	0.010	1	0
CAR MICH	-0.190	4	4	CAR PODO	0.310	4	0	EMP NIGR	0.006	5	2
ARC ALPI	-1.345	2	2	CAS TETR	-4.227	4	3	LED DECU	-0.380	2	2
LOI PROC	0.030	4	0	RHO LAPP	-0.130	1	1	VAC OLIG	-0.540	3	3
VAC VITI	-0.510	3	3	AGP VIOL	0.010	1	0	ARC LATI	0.010	1	0
CAL LAPP	0.010	1	0	CAL PURP	0.140	1	0	FES ALTA	0.505	2	0
FES BAFF	0.010	1	0	FES BRAC	0.090	3	0	HIE ALPI	-1.538	5	3
POA ALPG	1.105	2	0	POA ARCT	0.740	3	0	POA GLAU	9.510	1	0
TRS SPIC	0.217	4	0	JUN CAST	0.010	1	0	LUZ ARCU	0.025	2	0
LUZ CONF	0.168	5	3	TOF COCC	0.010	2	0	LYC CLAV	0.010	2	0
EPI ANGU	0.010	3	0	EPI LATI	0.010	5	0	POL VIVI	0.005	2	1
PYR SECU	0.010	2	0	ANE PARV	0.010	1	0	DRY INTE	0.780	3	0
DRY OCTO	1.020	4	3	DRY SYLV	0.010	1	0	POT ELEG	0.080	1	1
POT FROT	0.010	2	0	POT HYPA	0.010	1	0	POT NIVE	0.010	1	0
POT UNIF	0.010	1	0	POP BALS	0.010	3	0	SAL ALAX	4.967	6	0
SAL ARBU	1.530	2	0	SAL ARCT	0.010	1	0	SAL BARR	0.010	1	0
SAL DODG	0.010	2	0	SAL GLAU	0.010	3	0	SAL PLAN	2.608	5	2
SAL A XP	0.455	2	0	SAL RETI	0.010	1	0	PAR KOTZ	0.010	1	0
SAX DAVO	0.040	1	0	SAX PUNC	0.010	2	0	SAX REFL	0.010	1	0
SAX TRIC	1.000	3	0	PED CAPI	0.0	1	1	PED LANA	0.140	1	0
PED ARCT	0.010	1	0	BASIDIOM	0.395	2	0	ACA SCHL	0.340	1	0
ALE OCHR	-14.120	4	4	ASA CHRY	-1.450	2	2	CET CUCU	-2.908	6	6
CET ERIC	0.190	1	0	CET ISLA	-10.990	1	1	CET NIVA	-7.367	3	3
CET TILE	0.065	2	0	CLA ARBO	0.090	2	0	CLA RANG	-3.520	1	1
CLA STEL	-26.355	2	2	CLA CARI	0.140	1	0	CLA CHLO	0.170	2	0
CLA COCC	0.157	4	3	CLA G DI	0.010	1	0	CLA G GR	-0.175	2	2
CLA POCI	0.0	1	1	CLA PYXI	0.140	1	0	CLA SUBU	0.250	1	0
CLA UNCI	-0.460	1	1	DAC ARCT	-0.115	3	2	PEL APHT	2.050	2	0
PEL CANI	0.010	1	0	PEL POLY	4.190	1	0	PEL ROFE	0.010	1	0
SOL BISP	0.010	1	0	STE ALPI	0.010	1	0	STE GLAR	0.250	1	0
STE PASC	0.010	1	0	STE TOME	0.893	3	0	THA SUBO	0.010	1	0
THA VERM	-0.175	2	2	TON LOBU	1.100	1	0	SOIL LIC	4.607	3	0
SAX LICH	-4.390	3	3	CLADINA	0.140	1	0	LEC STIG	0.0	1	0
STERE SP	0.0	1	0	MOSS SPP	1.783	6	6	AUL TURG	0.010	1	0
BRYUM SP	0.0	1	0	CAM STEL	0.0	1	0	HYL SPLE	0.007	3	0
POG ALPI	0.0	1	0	POL JUNI	4.262	4	0	POL PILT	5.560	1	0
RHA CANE	0.0	1	0	RHA LANU	0.005	2	2	ENC PROC	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-5.663	0	3	ARN LOUI	-0.010	0	1	CAR MICH	-0.190	0	2
ARC ALPI	-0.942	0	4	CAS TETR	-8.510	0	2	LED DECO	-0.240	0	4
RHO LAPP	0.010	0	2	VAC OLIG	-0.403	0	3	VAC VITI	-0.510	0	3
CAL LAPP	-0.010	0	2	LOZ CONF	-0.010	0	1	TOF COCC	-0.140	0	1
LYC SELA	-0.034	0	5	SAL LANA	-0.010	0	2	PED LABR	-0.010	0	2
AGY RIGI	-0.187	0	6	ALE OCHR	-5.100	0	2	ASA CHRY	-0.700	0	1
CET ISLA	-4.125	0	4	CET LALV	-12.500	0	1	CET NIVA	-5.447	0	3
CET RICH	-0.010	0	1	CLA ARBU	-0.430	0	3	CLA RANG	-3.212	0	4
CLA STEL	-21.860	0	4	CLA AMAU	-0.640	0	2	CLA CARN	-0.010	0	2
CLA CHLO	0.0	0	1	CLA COCC	-1.210	0	2	CLA GONE	-0.010	0	2
CLA G GR	-0.220	0	4	CLA META	0.0	0	2	CLA POCI	0.0	0	2
CLA UNCI	-0.305	0	2	CLAD SPP	-0.513	0	3	COR DIVE	-0.010	0	2
DAC ARCT	-0.250	0	4	PAR SEPA	-0.190	0	2	SPH GLOB	-0.800	0	1
THA VERM	-0.290	0	1	UMB HYPE	-0.480	0	3	UMB H RA	-0.750	0	1
OMB PROB	-0.887	0	3	CRUSTOSE	-8.950	0	2	SAX LICH	-2.250	0	1
RHIZO SP	-4.153	0	4	RHI RIPA	-1.360	0	2	RHI EOPE	-1.360	0	2
RHI INAR	0.003	0	3	LEC DEMI	-0.650	0	2	OCH GEMI	-0.010	0	1
HEPATICS	0.005	0	6	AUL TURG	-0.010	0	3	CON TETR	0.0	0	2
DICRANUM	0.0	0	2	DIC ELON	-0.010	0	2	PTI CRIS	-0.010	0	2
RHA LANU	0.001	0	3								

1.2 Cover Differences (Cov.Dif.) Between False Start Roads (Distb.) and Their Controls (Contr.)

In *Cladonia stellaris-Alectoria ochroleuca* Tundra (n=2)

SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-4.150	1	1	LIN BORE	0.0	1	1	CER BEER	0.010	1	0
MIN ARCT	0.0	1	1	MIN BIFL	0.090	1	0	MIN MACR	2.140	1	0
ANT MONO	-0.100	1	1	ARN ALPI	0.090	1	0	ART ARCT	-0.005	2	2
PET HYPE	0.010	1	0	SEN LUGE	0.250	1	0	SOL MULT	-0.050	1	1
CAR BELL	0.010	1	0	CAR BRUN	0.010	1	0	CAR MEMB	0.010	1	0
CAR MICH	-0.825	2	2	CAR PODO	1.135	2	1	CAR LUGE	0.010	1	0
EMP NIGR	0.005	2	1	EQU ARVE	0.010	1	0	EQU SCIR	-0.180	1	1
CAS TETR	0.010	1	0	LEO DECU	0.005	2	1	LEO GROE	0.010	1	0
LOI PROC	0.040	1	0	VAC ULIG	-1.420	2	2	VAC VITI	-3.040	1	1
GEN GLAU	0.0	1	1	CAL LAPP	0.010	1	0	FES ALTA	5.810	1	1
HIE ALPI	-2.570	1	1	POA ALPN	0.540	1	0	POA ARCT	0.190	1	0
TRS SPIC	0.190	1	0	JUN CAST	0.010	1	0	LUZ MULT	0.010	1	0
LUZ CONF	4.540	1	0	LUZ NIVA	0.010	1	0	LUZ SPIC	-0.080	1	1
HEO MACK	0.010	1	0	TOF PUSI	0.010	1	0	LYC SELA	0.010	2	0
EPI ANGU	0.010	1	0	EPI LATI	0.0	1	1	BOT LUNA	0.010	1	0
OXY DIGY	-0.330	1	1	POL VIVI	0.0	1	1	ACO DELP	0.010	2	0
ANE PARV	0.0	1	1	DRY INTE	0.010	1	0	DRY SYLV	-4.240	1	1
POT ELEG	0.0	1	1	POT FRUT	0.0	1	1	SAL ALAX	0.0	1	1
SAL ARCT	0.040	1	0	SAL GLAU	6.900	1	0	SAL LANA	0.010	1	0
SAL PLAN	0.010	1	0	SAL A XP	0.040	1	0	SAL RETI	-4.490	1	1
PAR KOTZ	0.0	1	1	PED CAPI	-0.130	1	1	PED LABR	0.010	1	0
PED SUDE	-0.180	1	1	ALE OCHR	-7.550	1	1	CET COMM	0.010	1	0
CET CUCU	-1.030	2	2	CET ISLA	-7.220	1	1	CET LAEV	-12.460	1	1
CET NIVA	-7.450	1	1	CET RICH	-1.660	1	1	CLA STEL	-16.195	2	2
CLADO SP	0.0	1	0	CLA BACL	0.010	1	0	CLA COCC	0.005	2	1
CLA GONE	0.010	1	0	CLA G GR	0.010	1	1	CLA MACA	0.010	1	0
CLA META	0.010	1	0	CLA NORR	0.0	1	0	CLA PLEU	0.010	1	0
CLA POCI	0.010	1	1	CLA PYXI	0.0	1	0	CLA SUBU	-0.010	1	1
CLA UNCI	0.010	2	0	CLAD SPP	-1.430	1	1	DAC ARCT	-0.060	2	1
DAC BERI	-0.940	1	1	PEL APHT	0.145	2	1	PEL CANI	0.900	1	0
PEL MALA	0.010	1	0	SOLARINA	0.0	1	0	STE ALPI	1.910	1	1
STE PASC	1.920	1	0	STE TOME	0.040	1	0	UMB HYPE	0.0	1	1
SOIL LIC	13.625	2	1	SAX LICH	-0.560	1	1	LEC JURA	0.010	1	0
LEC AURI	0.340	1	0	HEPATICS	0.010	1	1	MOSS SPP	2.000	1	1
AUL TURG	0.005	2	1	CAM STEL	0.010	1	0	CER PURP	0.0	1	0
HYL SPLE	0.0	1	1	POL HYPE	0.010	1	0	POL JUNI	0.190	1	0
POL PILI	0.190	1	0	RHA LANU	0.0	1	0				

------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-4.090	0	1	SIL ACAU	-0.750	0	2	STELL SP	0.010	0	1
STE LAET	0.500	0	1	ARN LOUI	-0.010	0	1	CAR SCIR	-1.510	0	1
CAR VAGI	-0.140	0	1	ARC ALPI	-0.010	0	2	CAS TETR	-0.010	0	1
RHO LAPP	-0.140	0	1	VAC VITI	-0.010	0	1	HED ALPI	-0.010	0	1
TOF COCC	-0.140	0	1	ZYG ELEG	-0.010	0	1	PAP KEEL	-0.010	0	1
PIC GLAU	-0.010	0	1	POL ACUT	-0.010	0	1	POL VIVI	-0.040	0	1
THA ALPI	0.010	0	2	DRY OCTO	-10.950	0	1	SAL BARR	-4.090	0	1
SAX HIER	-0.010	0	1	PED CAPI	-0.010	0	1	AGY RIGI	-0.750	0	1
ASA CHRY	-2.250	0	1	CET NIVA	-0.800	0	1	CET RICH	0.010	0	1
CLA ARBU	-0.010	0	1	CLA MITI	-9.510	0	1	CLA RANG	-1.025	0	2
CLA AMAU	0.0	0	1	CLA CARN	0.0	0	1	CLA CHLO	0.0	0	2
CLA G DI	-3.410	0	1	CLA G GR	-3.410	0	1	CLA PHYL	0.0	0	1
CLAD SPP	-0.340	0	1	PAR HYPE	-0.010	0	1	SPH GLOB	-0.800	0	1
THA VERM	-0.290	0	1	UMB HYRA	-0.750	0	1	SAX LICH	-3.510	0	1
RHIZO SP	-4.540	0	1	RHI GLOG	0.0	0	1	BUE PAPI	0.0	0	1
OCH GEMI	-0.010	0	1	MOSS SPP	-0.140	0	1	POL JUNI	2.290	0	1

1.3 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In *Cladonia stellaris-Alectoria ochroleuca* Tundra (n=4)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	5.282	4	4	LIN BORE	4.340	1	0	MIN MACR	0.010	1	0
MIN R EL	0.190	1	0	SIL ACAU	0.025	2	0	SIE LAET	0.040	1	0
ANT MONO	0.010	1	0	ART ARCT	-0.203	3	1	ERI HUMI	0.010	1	0
PET FRIG	0.010	1	0	SOL MULT	1.510	1	0	TAR ALAS	0.040	1	0
CAR BELL	0.010	1	0	CAR MICH	5.015	2	2	CAR PODO	2.090	4	0
CAR SCIR	15.190	1	0	EMP NIGR	0.033	3	1	EQU SCIR	0.010	1	0
ARC ALPI	0.260	4	4	CAS TETR	-5.653	3	2	LEO DECU	1.347	3	3
LOI PROC	0.025	2	0	RHO LAPP	-0.100	1	1	VAC ULIG	-0.622	4	4
VAC VITI	9.087	3	3	GEN PROP	0.010	1	0	CAL LAPP	0.0	1	1
FES ALTA	0.010	2	0	HIE ALPI	0.370	4	1	POA ARCT	0.010	1	0
IRS SPIC	0.250	1	0	LUZ CONF	0.850	4	2	LUZ SPIC	0.010	1	0
TOF COCC	0.560	1	1	LYC ANNO	0.010	1	0	LYC CLAV	0.010	1	0
LYC SELA	-0.030	1	1	EPI ANGU	0.010	2	0	EPI LATI	0.090	1	0
BOT LUNA	0.010	1	0	PIC GLAU	0.010	2	0	OXY DIGY	0.010	1	0
PUL VIVI	0.040	1	0	AND CHAM	0.010	1	0	PYR GRAN	0.010	1	0
ANE PARV	0.800	1	0	DRY INTE	0.010	1	0	DRY OCTO	-8.810	1	1
DRY SYLV	0.010	1	0	POT ELEG	0.0	1	1	POT FRUT	0.010	1	0
ROS ACIC	0.010	1	0	RUB CHAM	0.010	1	0	POP BALS	0.010	1	0
SAL ALAX	1.897	3	0	SAL GLAU	0.075	2	0	SAL LANA	0.0	1	1
SAL PLAN	8.325	2	0	SAL POLA	1.260	1	0	SAL RETI	0.040	1	0
SAX AIZO	0.010	1	0	SAX HIER	0.010	1	0	PED LABR	0.005	2	1
ALE OCHR	-7.593	3	3	ASA CHRY	0.010	1	0	CET CUCU	-1.772	4	4
CET ISLA	-0.800	3	2	CET NIVA	-4.967	3	3	CET TILE	0.010	1	0
CLA ARBU	0.170	2	2	CLA RANG	-0.895	2	1	CLA STEL	-26.500	3	3
CLA CHLO	0.010	1	0	CLA COCC	-0.605	2	2	CLA CORN	0.750	1	0
CLA FIMB	0.010	1	0	CLA GONE	0.010	1	0	CLA G GR	-0.070	2	2
CLA PLEU	0.0	1	0	CLA POLY	0.010	1	0	CLA UNCI	0.010	1	0
CLA VERT	0.0	1	0	CLAD SPP	0.750	1	0	DAC ARCT	-0.170	2	2
DAC BERI	0.010	1	0	DMP VIRG	0.040	1	0	PAR SEPA	0.010	1	0
PEL APHT	0.010	1	0	PEL RUFE	0.010	1	0	STE PASC	0.190	1	0
STE SAXA	0.190	1	0	STE TOME	0.010	2	0	THA VERM	-0.280	1	1
SOIL LIC	3.595	2	0	SAX LICH	2.560	2	0	LEC STIG	0.950	2	0
OCH GEMI	0.680	2	0	HEPATICS	0.0	2	2	MOSS SPP	0.390	4	4
POLYT SP	6.900	1	0	AUL TURG	0.005	2	0	BRYUM SP	0.0	1	0
CER PURP	0.0	1	0	DICRANOI	0.010	1	0	DICRANUM	0.010	1	1
DIT FLEX	0.0	1	0	DREPANOC	0.010	1	0	HYL SPLE	0.0	2	0
HYP BAMB	0.0	1	0	HYP REVO	0.0	1	0	PLE SCHR	0.005	2	0
POL COMM	0.0	1	0	POL HYPE	3.290	2	0	POL JUNI	0.190	1	0
POL PILI	6.390	1	0	RHA LANU	0.0	2	2				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ARCT	0.010	0	1	SIL ACAU	-0.290	0	1	ARN LOUI	-0.010	0	1
CAR MICH	0.100	0	2	EMP NIGR	-0.010	0	1	CAS TETR	-17.010	0	1
LEO DECU	-0.800	0	1	VAC VITI	-1.510	0	1	CAL LAPP	-0.010	0	1
LYC SELA	-0.025	0	2	POL VIVI	-0.040	0	1	SAL LANA	-0.010	0	1
PED CAPI	-0.010	0	1	PED LABR	-0.010	0	1	AGY RIGI	-0.235	0	4
ALE OCHR	-5.100	0	1	ASA CHRY	-2.250	0	1	CET ISLA	-2.020	0	1
CET LAEV	-12.500	0	1	CET NIVA	-8.590	0	1	CET RICH	-0.010	0	1
CLA ARBU	-0.640	0	1	CLA RANG	-2.585	0	2	CLA STEL	-16.500	0	1
CLA AMAU	-0.640	0	2	CLA CHLO	0.0	0	1	CLA COCC	-1.210	0	1
CLA G GR	-0.070	0	2	CLA POCI	0.0	0	1	CLA UNCI	-0.010	0	1
CLAD SPP	-0.340	0	1	COR DIVE	-0.010	0	2	DAC ARCT	-0.195	0	2
PAR SEPA	0.190	0	2	SPH GLOB	-0.800	0	1	UMB HYPE	-0.480	0	3
UMB PROB	0.887	0	3	CRUSTOSE	-8.950	0	2	SAX LICH	-5.930	0	2
RHIZO SP	-6.165	0	2	RHI RIPA	-1.360	0	2	RHI EUPE	-1.360	0	2
RHI INAR	0.010	0	1	LEC DEMI	-0.650	0	2	OCH GEMI	-0.010	0	1
HEPATICS	-0.250	0	3	AUL TURG	0.010	0	1	DICRANUM	0.0	0	1
RHA LANU	0.0	0	1								

1.4 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.)

In Cladonia stellaris-Alectoria ochroleuca Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	10 990	1	1	STE LAET	0 010	1	0	CAR MICH	0 0	1	1
ARC ALPI	-1 010	1	1	LEO DECU	2 450	1	1	VAC ULIG	2 870	1	1
VAC VITI	2 540	1	1	FES ALTA	0 010	1	0	HIE ALPI	0 190	1	0
EPI ANGU	0 010	1	0	EPI LATI	0 010	1	0	PIC GLAU	0 010	1	0
POT FRUT	0 010	1	0	SAL PLAN	0 040	1	0	PED LABR	0 010	1	0
CET CUCU	-0 100	1	1	CET LAEV	0 010	1	0	CLA RANG	0 250	1	0
CLA STEL	-10 190	1	1	CLA ECMO	0 0	1	0	CLA G GR	0 010	1	1
CLA PLEU	0 0	1	0	CLAU SPP	0 090	1	0	DAC ARCT	0 0	1	1
PEL APHT	7 560	1	0	HEPATICS	-0 010	1	1	MOSS SPP	62 460	1	1
AUL TURG	0 0	1	0	PLE SCHR	0 0	1	0	POL JUNI	0 0	1	0
PTI CRIS	0 0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR
CAS TETR	-0 010	0	1	LYC SELA	0 010	0	1	AGY RIGI	-0 010	0	1
ALE OCHR	-10 540	0	1	CET ISLA	-1 460	0	1	CET NIVA	-7 050	0	1
CLA COCC	-0 010	0	1	CLA UNCI	-0 010	0	1	UMB HYPE	1 260	0	1
UMB PROB	-1 260	0	1	SAX LICH	-8 350	0	1	RHIZO SP	-7 790	0	1
RHI INAR	-0 010	0	1	RHA LANU	-0 010	0	1				

1.5 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Cladonia stellaris-Alectoria ochroleuca Tundra (n=5)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR
BET GLAN	-2 920	3	3	OTHR VAS	0 040	1	0	LIN BORE	0 0	1	1
CER BEER	0 040	1	0	BETULA	0 010	1	0	MIN ARCT	0 400	2	1
MIN BIFL	0 010	1	0	MIN MACR	0 207	3	0	MIN ROSS	0.010	1	0
STELL SP	0 0	1	1	ANT EKMA	0 010	2	0	ANT MONO	-0 180	1	1
ARN ALPI	0 010	3	0	ARN LOUI	0 010	1	0	ART ARCT	-0 302	4	3
PET FRIG	0 010	1	0	PET PALM	0.010	1	0	SEN ATRO	0 010	1	0
SEN LUGE	0 010	1	0	SOL MULT	-0.740	1	1	TARAX SP	0 010	1	0
CAR BELL	0 010	1	0	JUN HORI	0 010	1	0	CAREX SP	0 010	1	0
CAR GLAC	0 090	1	0	CAR MICH	0 140	4	4	CAR PODO	4 090	1	0
ERI VAGI	0 010	1	0	EMP NIGR	0 005	4	2	EQU ARVE	0 010	1	0
EQU SCIR	-0 180	1	1	AND POLI	0 010	1	0	ARC ALPI	-0.897	3	3
CAS TETR	5 667	3	3	LED DECU	-0 306	5	5	LEO GROE	0.010	2	0
LOI PROC	0 010	3	0	RHO LAPP	0 005	4	2	VAC ULIG	-1 082	4	4
VAC VITI	-1 523	3	3	GIN GLAU	0 0	1	1	CAL LAPP	0 005	2	1
FES ALTA	-4 530	1	1	FES BRAC	0 040	1	0	HIE ALPI	-1.280	2	1
POA ALPN	0 250	1	0	POA ARCT	0.075	2	0	TRS SPIC	0 140	1	0
LUZ CONF	0 375	4	2	LUZ SPIC	-0 080	1	1	TOF COCC	-0 060	4	2
LYC ANNO	0 010	1	0	LYC CLAV	0 010	1	0	LYC SELA	-0 030	1	1
EPI ANGU	0 010	1	0	EPI LATI	4 330	1	1	BOT LUNA	0 010	1	0
PIC GLAU	0 010	2	0	ARM MARI	0 010	1	0	OXY DIGY	-0.330	1	1
POL VIVI	0 005	2	1	PYROL SP	0 010	1	0	ANE PARV	0 0	1	1
DRY INTE	0 010	1	0	DRY OCTO	-5 750	2	2	POT ELEG	1.705	2	1
POT UNIF	0 305	2	0	POP BALS	0 010	2	0	SAL ALAX	2 190	5	1
SAL DOUG	0 010	1	0	SAL PLAN	0.040	4	1	SAL A XP	0 010	1	0
SAL RETI	-2 240	2	1	PAR KOTZ	0 0	1	1	SAX FLAG	0 010	1	0
SAX OPPO	0 010	1	0	PED LANA	0 010	1	0	ALE OCHR	-10 790	4	4
ASA CHRY	-2 240	1	1	CET CUCU	-2 607	4	4	CET ERIC	0 010	1	0
CET ISLA	-7 500	1	1	CET LAEV	-6.240	2	1	CET NIVA	-5 050	3	3
CET RICH	-1 860	1	1	CET TILE	0 040	1	0	CLA ARBU	0.0	1	1
CLA STEL	-23 355	2	2	CLADO SP	0 010	1	0	CLA COCC	0 290	1	0
CLA CORN	0 010	1	0	CLA FURC	0 010	1	0	CLA G DI	0 250	1	0
CLA META	0 010	1	0	CLA PLEU	0 040	1	0	CLA PYXI	0 010	1	0
CLA UNCI	0 005	2	1	DAC ARCT	0 010	1	0	DAC BERI	-0 940	1	1
PAR SEPA	0 010	1	0	PEL APHT	-1 200	1	1	PEL CANI	0.010	1	0
PEL RUFE	0 010	1	0	STE ALPI	0 080	1	1	STE PASC	0 100	2	0
STE SAXA	0 190	1	0	STE TOME	0 340	1	0	THA SUBU	0 010	2	0
THA VERM	-0.170	3	2	TON LOBO	8 020	1	0	SOIL LIC	0.533	3	1
SAX LICH	2 667	4	3	LEC JURA	0 0	1	0	LEC STIG	1 520	2	0
LEC MACR	0 0	1	0	MOSS SPP	-0 243	3	3	POLYT SP	2 390	2	0
AUL TURG	0 010	1	0	CER PURP	0 010	1	0	DRE UNCI	0 010	2	0
POG ALPI	0 0	1	0	POL JUNI	2 540	3	1	RHA CANE	0 010	1	0
RHA LANU	-0 005	2	2	POG DENT	0 0	1	0				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	5 840	0	2	SIL ACAU	-0 750	0	2	STE LAET	-0 500	0	1
ARN LOUI	-0 010	0	1	CAR MICH	-1 660	0	1	CAR PODO	-0 590	0	1
CAR SCIR	-1 510	0	1	CAR VAGI	-0 140	0	1	ARC ALPI	-0 530	0	2
CAS TETR	-0 010	0	1	VAC ULIO	-0 600	0	1	VAC VITI	0 010	0	2
HIE ALPI	-2 580	0	1	HEO ALPI	0 010	0	1	ZYO ELEG	-0 010	0	1
LYC SELA	-0 025	0	2	PAP KEEL	-0.010	0	1	PIC GLAU	-0.010	0	1
POL ACUT	0 010	0	1	POL VIVI	-0 010	0	1	THA ALPI	-0 010	0	2
ORY SYLV	4 250	0	1	POT FRUT	-0 010	0	1	SAL BARR	-4.090	0	1
SAL LANA	0 010	0	1	SAX HIER	-0 010	0	1	PED CAPI	-0 075	0	2
PED LABR	-0 010	0	1	PED SUDE	-0.190	0	1	AGY RIGI	-0 235	0	4
ASA CHRY	-0 700	0	1	CET CUCU	-0.650	0	1	CET ISLA	-4.827	0	3
CET NIVA	-7 820	0	2	CET RICH	-0 010	0	1	CLA ARBU	-0 640	0	1
CLA MITI	-9 510	0	1	CLA RANG	-2.432	0	4	CLA STEL	-18 813	0	3
CLA AMAU	-0 320	0	2	CLA CARN	-0 005	0	2	CLA CHLO	0 0	0	2
CLA CUCC	-0 305	0	4	CLA GONE	-0 010	0	1	CLA O OF	-3 410	0	1
CLA G GR	-0 832	0	5	CLA META	0 0	0	1	CLA PHYL	0 0	0	1
CLA POCI	0 0	0	2	CLA SUBU	-0.010	0	1	CLA UNCI	-0 600	0	1
CLAU SPP	-0 937	0	3	COR DIVE	-0 010	0	1	DAC ARCT	-0 195	0	4
PAR SEPA	-0 190	0	1	PAR HYPE	-0 010	0	1	SPH GLOB	-0 800	0	1
UMB HYPE	0 453	0	3	UMB H RA	-0 750	0	1	UMB PROB	-0 980	0	2
CRUSTOSE	-8 950	0	1	SAX LICH	-2 250	0	1	RHIZO SP	-4 823	0	3
RHI RIPA	-1 360	0	1	RHI EUPE	-1 360	0	1	RHI INAR	-0 005	0	2
RHI GEOG	0 0	0	1	LEC DEMI	-0 650	0	1	BUE PAPI	0 0	0	1
UCH GEMI	0 010	0	1	HEPATICS	-0 005	0	4	MOSS SPP	-0 215	0	2
AUL TURG	0 010	0	2	CON TETR	0 0	0	1	DICRANUM	0 0	0	1
DIC ELON	-0 010	0	1	HYL SPLE	0 0	0	1	PTI CRIS	-0 010	0	1
RHA LANU	0 0	0	1								

I.6 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.)

In Cladonia stellaris-Alectoria ochroleuca Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.
BET GLAN	-7 580	1	1	BETULA	0 010	1	0	MIN MACR	6 390	1	0
ARN ALPI	0 010	1	0	ART ARCT	0 250	1	1	CAR MICH	1 120	1	1
CAR PODO	1 310	1	0	EMP NIGR	2 090	1	0	ARC ALPI	-2 690	1	1
CAS TETR	0 0	1	1	LED DECU	2 080	1	1	RHO LAPP	0 0	1	1
VAC ULIG	0 0	1	1	VAC VITI	0 030	1	1	POA ARCT	0 010	1	0
LUZ CONF	0 130	1	1	TOF COCC	0 010	1	0	TOF PUSI	0.010	1	0
LYC SELA	-0 030	1	1	DRY OCTO	7 650	1	1	POT ELEG	0 010	1	0
POT RUBR	0 010	1	0	SAL ALAX	9 690	1	0	SAL PLAN	-3 490	1	1
SAL RETI	0 010	1	0	ALE OCHR	-19 910	1	1	ASA CHRY	-0 660	1	1
CET CUCU	-3 930	1	1	CET LAEV	0 140	1	0	CET NIVA	-6 860	1	1
CLA STEL	-21 910	1	1	CLA CARN	0 0	1	1	STE PASC	0 190	1	0
THA VERM	-0 240	1	1	UMB PROB	1 310	1	0	SOIL LIC	4 900	1	0
LEC STIG	3 050	1	0	MOSS SPP	-0 100	1	1	POLYT SP	4 590	1	0
AUL TURG	0 0	1	1	CER PURP	0 0	1	0	CON TLTR	0 0	1	1
POG ALPI	0 0	1	0	RHA LANU	0 0	1	1	POG DENT	0 010	1	0

------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
HIE ALPI	-2 580	0	1	AGY RIGI	-0 090	0	1	CET ISLA	-11 000	0	1
CLA RANG	-3 610	0	1	CLA COCC	0 0	0	1	CLA GONE	-0 010	0	1
CLA G GR	-0 600	0	1	CLA META	0 0	0	1	CLA POCI	0 0	0	1
CLA UNCI	-0 600	0	1	CLAD SPP	-0 600	0	1	DAC ARCT	-0 250	0	1
SAX EICH	-2 250	0	1	RHIZO SP	-2 140	0	1	RHI INAR	0 0	0	1
HEPATICS	-0 010	0	1	DIC ELON	-0 010	0	1	PTI CRIS	-0 010	0	1

I.7 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.)

In Cladonia stellaris-Alectoria ochroleuca Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-5 300	1	1	CAR MICH	0 0	1	1	CAS TETR	-17 000	1	1
VAC VITI	-1 500	1	1	LUZ CONF	0 0	1	1	SAL PLAN	0 010	1	0
OCH ANDR	0 010	1	0	SAX LICH	0 290	1	0	RHI GEOG	0 0	1	0
LEC MACR	0 0	1	0	MOSS SPP	-0 490	1	1	POL JUNI	0 010	1	0
RHA CANE	0 010	1	0	OLIGOTRI	0 0	1	0				

- ------ IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
EMP NIGR	-0 010	0	1	ARC ALPI	-0 010	0	1	LED DECU	-0 800	0	1
VAC ULIG	-C 600	0	1	CAL LAPP	-0 010	0	1	LYC SELA	-0 040	0	1
SAL LANA	-0 010	0	1	PED LABR	-0 010	0	1	AGY RIGI	-0 090	0	1
ALE OCHR	-5 100	0	1	CET CUCU	3 610	0	1	CET ISLA	-2 020	0	1
CET NIVA	-8 590	0	1	CLA ARBU	-0 640	0	1	CLA RANG	-4 070	0	1
CLA STEL	-11 000	0	1	CLA AMAU	-0 640	0	1	CLA COCC	-1 210	0	1
CLA G GR	-0 140	0	1	COR DIVE	-0 010	0	1	DAC ARCT	0 250	0	1
PAR SEPA	0 190	0	1	UMB HYPE	-0 090	0	1	UMB PROB	-0 700	0	1
CRUSTOSE	8 950	0	1	RHI RIPA	-1 360	0	1	RHI EUPE	-1 360	0	1
LEC OLMT	-0 650	0	1	HEPATICS	0 0	0	1	DICRANUM	0 0	0	1
RHA LANU	0 0	0	1								

J.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Cassiope tetragona Tundra (n=8)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0 0	1	1	CER BFER	0 010	1	0	MEL APET	0 0	2	2
MIN ARCT	0 257	6	3	MIN R EL	0 070	5	2	MIN ROSS	1 980	1	1
MIN RUBE	0 010	1	0	SIL ACAU	-1 806	5	5	STELL SP	0 010	1	0
STE LAET	0 010	2	0	STE MONA	0.010	1	0	ANT DENS	0 010	2	0
ANT MONO	0 010	1	0	ARN ALPI	-0.240	3	1	ART ARCT	0.010	1	0
CHR INTE	-0 010	2	1	PET HYPE	0.010	1	0	SEN CYMB	-0 077	2	2
SOL MULT	0.010	1	0	BRA PURP	0.160	5	1	DRA CORY	0 495	4	2
DRA LACT	0 010	1	0	EUT EDWA	0.140	1	0	PAR NUDI	0 005	2	1
CAR ATFU	0 010	1	0	CAR GYNO	0.010	1	0	CAR GLAC	0 030	3	0
CAR MEMB	0 006	5	2	CAR MICH	0 010	1	0	CAR MISA	-0 210	2	1
CAR PETR	-3 140	2	2	CAR RUPE	-17 990	2	2	CAR SCIR	-2 580	3	3
ERI ANGU	0 003	4	3	EMP NIGR	0 010	1	0	EQU PALU	0 010	1	0
EQU VARI	0 010	1	0	ARC ALPI	0.003	2	2	RHO LAPP	-0.790	2	2
ARC LATI	0 010	1	0	DES CAES	0.010	1	0	ELY INNO	0 010	1	0
FES ALTA	0 005	2	1	FES BRAC	0 010	1	0	POA SP	0 010	1	0
POA ALPN	0 010	2	0	POA ARCT	0 090	1	0	POA GLAU	1 525	2	0
IRS SPIC	0 087	3	1	JUN BALT	0 010	1	0	JUN BIGL	0 005	2	1
JUN CAST	0 010	1	0	JUN ALBE	0 010	1	0	LUZ NIVA	0 0	1	1
HED MACK	-1 250	2	2	OXY JORD	0 0	1	1	OXY NIGR	-0 080	1	1
OXY SHEL	0 010	1	0	LLO SERO	0 040	2	0	TOF PUSI	-0 352	3	3
EPI LATI	0 010	2	0	PAP KEEL	0 395	2	2	PIC GLAU	0 010	1	0
ARM MARI	0 080	1	1	OXY DIGY	0 010	1	0	POL VIVI	-0 638	5	4
AND CHAM	-0 033	6	3	PYR SECU	0 0	1	1	ANE PARV	0 002	3	2
DRY DRUM	0 010	2	0	DRY INTE	-38 677	8	8	DRY SYLV	0.010	1	0
POT BIFL	-3 905	4	3	POT FRUT	0 005	4	2	POT HYPA	0 010	1	0
POP BALS	0 010	2	0	SAL ALAX	7 033	7	3	SAL ARBU	0 010	6	0
SAL ARCT	-0 793	6	3	SAL DODG	0 007	4	2	SAL GLAU	0 017	4	0
SAL MYRI	0 010	1	0	SAL POLA	0 640	1	1	SAL A XP	0 453	3	2
SAL RETI	-0 930	5	4	PAR PALU	0 010	1	0	SAX AIZO	0.060	3	3
SAX OPPO	-0 621	7	6	CASTI SP	0 010	1	0	CAS CAUD	0 010	1	0
PED CAPI	0 0	1	1	PED LANA	0 013	3	2	PED SUDE	0 0	2	2
TER ALGA	0 800	1	0	ALE OCHR	-7.090	1	1	CET CUCU	-4 430	1	1
CET NIVA	-0 280	1	1	CET TILE	-0 560	3	3	DAC ARCT	-0.330	1	1
DAC RAMU	0 010	1	0	PEL RUFE	0 010	1	0	CRUSTOSE	0 140	1	0
SOIL LIC	0 840	3	1	MOSS SPP	-6 283	3	3	ABI ABIE	0.010	1	0
BRYUM SP	0 010	1	0	BRY PSEU	0 010	1	0	CAM S AR	0 010	1	0
CAM STEL	0 010	2	0	CER PURP	0 0	1	0	DRE REVO	0 0	1	1
HYP BAMB	0 0	3	3	ORT CRYS	0 010	1	0	POHLIA	0.010	1	0
TET MNIO	0 010	1	0	TOM NITE	0 0	1	1	TOR TORT	0 0	1	0
LES RADI	0 010	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV.DIF.	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-0 010	0	2	MIN ARCT	-0.700	0	1	MIN R EL	-0 140	0	2
SIL ACAU	-1 130	0	2	ARN ALPI	-0 010	0	1	CHR INTE	-0 020	0	3
SAU ANGU	-0 053	0	3	SEN ATRO	-0.025	0	2	SEN LUGE	-0 010	0	1
BRA PURP	-0 010	0	1	CAR BELL	-0 010	0	1	PAR NUDI	-0.020	0	3
CAR ATFU	-0 380	0	2	CAR CAPI	-0.010	0	1	CAR MEMB	-0.010	0	1
CAR MISA	-1 303	0	3	CAR PETR	-0.345	0	2	CAR PODO	-14 500	0	1
CAR RUPE	-3 095	0	2	CAR SCIR	-2 395	0	4	CAR VAGI	-0 010	0	1
ERI ANGU	-11 755	0	2	ERI CAIL	-0 250	0	1	KOB MYOS	-0 010	0	1
KOB SIMP	-0 758	0	5	EQU VARI	-0.940	0	2	AND POLI	-0.315	0	4
ARC ALPI	-0 025	0	2	CAS TETR	-4 024	0	7	LED GROE	-0 010	0	2
RHO LAPP	-1 453	0	3	VAC ULIG	-2.916	0	5	GEN PROP	-0 010	0	1
ARC LATI	-0 140	0	1	FES ALTA	-0.010	0	1	JUN BIGL	-0 010	0	1
JUN ALBE	-0 180	0	3	LUZ NIVA	-0.600	0	1	LUZ PARV	-0 010	0	1
TRI MARI	-0 010	0	1	AST UMBE	0 010	0	1	HED ALPI	-0 170	0	3
OXYTR SP	-0 190	0	2	OXY NIGR	-0.090	0	1	PIN VULG	-0.010	0	3
TOF PUSI	-0 125	0	4	LYC SELA	-0 010	0	1	BOT LUNA	-0.010	0	1
PAP KEEL	-0 010	0	2	PIC GLAU	0.010	0	2	POL BIST	-0.470	0	2
POL VIVI	-0 100	0	3	WOO GLAB	-0 010	0	1	AND CHAM	-0.025	0	2
PYR ASAR	-0 010	0	5	ANE PARV	-0 057	0	3	THA ALPI	-0.316	0	8
POT BIFL	-3 470	0	2	POT FRUT	-0 010	0	1	SAL DODG	-0 010	0	1
SAL POLA	-0 010	0	1	SAL RETI	-1 747	0	3	SAX HIRC	-0 010	0	2
PED CAPI	-1 576	0	5	PED LANA	-0 097	0	3	PED ARCT	-0 040	0	1
PED SUDE	-0 075	0	2	ALE OCHR	-3 062	0	5	ASA CHRY	-0 650	0	3
CET CUCU	-3 327	0	7	CET DELI	-1 360	0	1	CET ERIC	-0.010	0	2
CET ISLA	-2 207	0	6	CET LAEV	-0 500	0	1	CET NIVA	-0 414	0	7
CET PINA	-0 010	0	2	CET RICH	-0 180	0	3	CET TILE	-1 304	0	5
CLA ARBU	0 940	0	5	CLA RANG	-0 800	0	1	CLA STEL	-0 650	0	2
CLA ACUM	-0 010	0	1	CLA CHLO	0 0	0	1	CLA G GR	-0 100	0	2
CLA MAJO	0 0	0	1	CLA PHYL	0 0	0	1	CLA POCI	-0 227	0	6
CLA PYXI	-0 010	0	1	CLA UNCI	-0 340	0	1	CLAD SPP	-0 340	0	1

continued

J.1 --- in controls but not in disturbances --- (continued)

COR OIVE	-0.010	0	1	DAC ARCT	-0.832	0	6	DAC RAMU	-0.163	0	3
LEC EPIB	-0.495	0	4	LEC URCE	-1.530	0	3	OCH ULIG	-1.920	0	2
PEL APHT	-0.010	0	1	PEL CANI	-0.010	0	2	PER DACT	-0.290	0	1
POL SENO	-1.460	0	1	SOL BISP	-0.060	0	7	THA SUBU	-0.703	0	7
CRUSTOSE	-9.690	0	1	SOIL LIC	-2.004	0	5	SAX LICH	-4.440	0	3
RIN ROST	-0.800	0	1	VER MURA	0.0	0	2	LEC STIG	-0.070	0	4
OCH INAE	-0.010	0	1	HEPATICS	0.0	0	2	MOSS SPP	-5.230	0	5
AUL ACUM	0.0	0	1	ENCALYPT	0.0	0	1	CAM STEL	0.0	0	1
CER PURP	0.0	0	1	CIR CIRR	-0.010	0	1	CRY HYME	-0.010	0	2
DICRANUM	0.0	0	1	DITRICHA	0.0	0	1	DIT FLEX	-0.008	0	4
DREPANOC	-0.010	0	1	HYL SPLE	-0.007	0	3	HYPNUM	0.0	0	1
HYP BAMB	-0.006	0	5	HYP CUPR	0.0	0	1	HYP PROC	-0.010	0	1
HYP REVO	0.0	0	1	MYU JULA	-0.010	0	1	ORT CRYS	-0.010	0	1
POL STRI	0.0	0	1	RHA LANU	-0.005	0	4	RHY RUGO	-0.005	0	4
TOM NITE	0.0	0	5	TOR ARCT	-0.005	0	2	TOR FRAG	-0.010	0	2
TOR TORT	0.0	0	2	SCHISTIO	0.0	0	1	ENC PROC	-0.010	0	1
ENC ALPI	0.0	0	1	TOR LATI	-0.010	0	1	FIS OSMU	-0.010	0	2

J.2 Cover Differences (Cov.Dif.) Between False Start Roads (Distb.) and Their Controls (Contr.)

In <u>Dryas integrifolia-Cassiope tetragona</u> Tundra (n=2)

SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-2.130	1	1	MEL APET	0.140	1	0	MIN ARCT	0.010	1	0
MIN R EL	0.090	2	0	SIL ACAU	-0.740	1	1	STE LAET	0.010	1	0
ANTEN SP	0.040	1	0	ARN ALPI	0.140	1	0	ARN LESS	0.010	1	0
CHR INTE	3.000	1	0	SEN LUGE	0.010	1	0	SOL MULT	0.0	1	1
BRA PURP	0.0	1	1	BRA RICH	0.410	1	1	PAR NUDI	0.0	1	1
CAR ATFU	0.010	1	0	CAR GLAC	-0.515	2	1	CAR MEMB	0.010	1	0
CAR MISA	0.0	1	1	CAR SCIR	-4.520	2	2	EMP NIGR	0.0	1	1
EQU VARI	0.010	1	0	ARC ALPI	-7.630	1	1	ELY INNO	0.0	1	1
POA GLAU	0.010	1	0	TRS SPIC	0.100	2	0	JUN ALBE	0.0	1	1
OXY SHEL	0.0	1	1	LLO SERO	0.010	1	0	TOF PUSI	-0.960	1	1
ZYG ELEG	0.010	1	0	EPI ANGU	0.010	1	0	POL VIVI	0.200	2	2
AND CHAM	-0.900	2	2	PYROL SP	0.010	1	0	ANE PARV	-0.265	2	2
THA ALPI	0.335	2	2	DRY INTE	-4.400	2	2	DRY SYLV	0.010	1	0
POT FRUT	0.0	1	1	SAL ALAX	11.480	2	0	SAL ARBU	0.010	1	0
SAL ARCT	0.005	2	1	SAL DODG	0.130	1	1	SAL POLA	0.010	1	0
SAL RETI	0.015	2	2	SAX AIZO	0.190	2	0	SAX OPPO	-1.685	2	2
CET RICH	-0.860	1	1	SOIL LIC	-5.030	1	1	SAX LICH	-5.030	1	1
POLYB SP	0.010	1	0	MOSS SPP	0.0	2	2	BRYUM SP	0.0	1	0
DIT FLEX	0.005	2	0	DRE REVO	0.0	1	0	HYP BAMB	0.0	1	1
PLA JUNG	0.010	1	0								

------- IN CONTROLS BUT NOT IN DISTURBANCES ---

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ROSS	-0.390	0	1	SIL ACAU	-4.950	0	1	ANT DENS	-0.040	0	1
ARN ALPI	0.010	0	1	CHR INTE	-0.040	0	1	SAU ANGU	-0.010	0	1
DRA CORY	-0.010	0	1	PAR NUDI	-0.010	0	1	CAR NARD	-1.260	0	1
CAR RUPE	-2.640	0	2	ERI ANGU	-0.010	0	1	AND POLI	-0.010	0	1
CAS TETR	-11.260	0	2	RHO LAPP	-0.010	0	1	VAC ULIG	-0.010	0	2
FES ALTA	-0.010	0	1	OXYTR SP	-0.010	0	1	PIN VULG	-0.010	0	1
LLO SERO	-0.010	0	1	TOF PUSI	-0.010	0	1	PAP KEEL	-0.010	0	1
DRY OCTO	-1.870	0	1	POT FRUT	-0.010	0	1	SAL A XP	0.010	0	1
PED CAPI	-0.010	0	1	PED LANA	-0.010	0	2	PED SUDE	-0.075	0	2
ALE OCHR	-0.013	0	1	CET CUCU	-0.010	0	1	CET DELI	-0.685	0	2
CET ERIC	1.810	0	2	CET NIVA	-9.255	0	2	CET TILE	-6.255	0	2
CLA ARBU	0.010	0	1	CLADO SP	-0.010	0	1	CLA POCI	-0.010	0	1
CLA PYXI	-0.130	0	2	COR ACUL	-0.010	0	1	DAC ARCT	-0.010	0	1
DAC BERI	0.410	0	1	DAC RAMU	-0.010	0	1	LEC URCE	-0.750	0	1
PEL CANI	-0.010	0	1	SOL BISP	-0.025	0	2	THA SUBU	3.760	0	2
THA VERM	-0.010	0	1	SOIL LIC	-1.000	0	1	SAX LICH	-13.060	0	1
LEC STIG	0.0	0	1	POL INTE	0.0	0	1	HEPATICS	-0.010	0	1
HYL SPLE	0.010	0	1	HYPNUM	-0.010	0	1	HYP BAMB	-0.010	0	1
TOM NITE	0.0	0	1	TOR TORT	0.0	0	1				

J.3 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In <u>Dryas integrifolia-Casslope tetragona</u> Tundra (n=5)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0.0	2	2	ARE HUMI	0.140	1	0	MEL APET	0.003	3	2
MIN ARCT	-0.150	3	3	MIN BIFL	0.010	1	0	MIN R EL	0.352	4	3
MIN ROSS	0.200	1	1	MIN RUBE	0.010	1	0	SIL ACAU	-0.572	4	4
STE LONG	0.250	1	0	ANT DENS	3.460	1	0	ANT EKMA	0.010	1	0
ANT MONO	0.010	2	0	ARN ALPI	0.715	2	1	ARI ARCT	0.010	1	0
CHR INTE	0.560	1	1	ERI HUMI	0.140	1	0	SAU ANGU	0.0	1	1
SEN ATRO	0.0	1	1	SEN LUGE	0.0	1	1	SEN CYMB	-0.195	2	2
SOL MULT	0.010	1	0	BRA PURP	0.077	4	0	DRA CORY	0.140	1	0
DRA LACT	0.040	1	0	EUT EDWA	0.010	1	0	LES ARCT	0.600	1	0
PAR NUDI	0.0	1	1	CAR GLAC	0.785	2	0	CAR MEMB	3.167	3	3
CAR MISA	-0.410	3	2	CAR PETR	-2.500	1	1	CAR PODO	-13.850	1	1
CAR ROPE	-13.075	2	2	CAR SCIR	-1.080	5	5	ERI ANGU	4.197	3	3
KOB SIMP	-0.093	3	3	EQU SCIR	0.010	1	0	EQU VARI	-0.480	2	1
AND POLI	0.0	1	1	ARC ALPI	0.0	1	1	CAS TETR	-9.500	1	1
RHO LAPP	-0.790	1	1	VAC ULIG	-7.265	2	2	ELY INNO	0.010	1	0
FES BRAC	0.010	1	0	POA SP	0.075	2	0	POA ALPN	0.010	1	0
TRS SPIC	0.125	2	1	JUN BIGL	0.030	1	1	JUN ALBE	0.190	1	0
LUZ NIVA	-0.295	2	2	LUZ PARV	0.010	1	0	HED ALPI	-0.160	3	3
HED MACK	0.475	2	2	OXYTR SP	0.100	1	1	OXY NIGR	-0.050	1	1
PIN VULG	0.0	2	2	LLO SERO	0.017	4	0	TOF PUSI	-0.455	2	2
EPI LATI	0.010	3	0	PAP KEEL	0.0	2	2	ARM MARI	0.0	1	1
OXY DIGY	0.010	1	0	POL BIST	-0.460	2	2	POL VIVI	-0.432	4	4
AND CHAM	0.130	6	4	PYR ASAR	0.0	1	1	ANE PARV	0.170	4	3
THA ALPI	-0.123	3	3	DRY INTE	-36.004	5	5	POT BIFL	-4.067	4	4
POT FRUT	0.200	3	2	POP BALS	0.010	1	0	SAL ALAX	3.240	4	2
SAL ARBU	0.010	1	0	SAL ARCT	-1.027	3	1	SAL DODG	-0.020	2	1
SAL GLAU	0.150	2	0	SAL PULA	0.045	2	1	SAL RETI	-1.045	4	4
PAR PALU	0.010	1	0	SAX AIZO	1.817	3	3	SAX OPPO	0.770	3	3
CASTI SP	0.010	1	0	PED CAPI	0.017	3	1	PED LANA	0.740	1	1
PED SUDE	0.047	3	2	CET CUCU	-1.650	1	1	CET NIVA	-0.280	1	1
CET RICH	-0.030	4	1	CET TILE	-1.040	1	1	POL SENO	0.0	1	0
SOLARINA	0.010	1	0	SOL BISP	0.050	2	2	THA SUBU	0.0	1	1
SOIL LIC	-2.715	2	2	SAX LICH	-1.400	2	1	VER MURA	0.083	3	1
HEPATICS	0.005	2	0	MOSS SPP	-3.262	5	5	BRYUM SP	0.010	1	0
BRY PSEU	0.0	1	0	CAM STEL	0.007	3	0	DICRANUM	0.0	1	0
DIT FLEX	0.0	2	1	DRE REVO	0.0	1	0	HYP BAMB	0.0	3	3
ORT CRYS	0.010	1	0	ORT STRI	0.010	1	0	TOM NITE	0.0	1	0
TOR TORT	0.0	2	0	TOR RURA	0.0	1	0				

------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-0.010	0	1	SIL ACAU	-1.360	0	1	CHR INTE	-0.010	0	1
SAU ANGU	-0.140	0	1	SEN ATRO	0.010	0	1	CAR BELL	-0.010	0	1
DRA CORY	0.010	0	1	PAR NUDI	-0.010	0	1	CAR ATFU	0.010	0	1
CAR PETR	-1.670	0	2	CAR RUPE	-1.660	0	1	KOB SIMP	-0.950	0	1
AND POLI	-0.555	0	2	ARC ALPI	0.010	0	1	CAS TETR	-0.405	0	4
LLU GROE	-0.010	0	2	RHO LAPP	-0.405	0	2	VAC ULIG	-0.010	0	1
GEN PROP	-0.010	0	1	FES ALTA	-0.010	0	2	JUN BIGL	-0.010	0	1
JUN ALBL	0.140	0	1	LUZ PARV	-0.010	0	1	AST UMBE	-0.010	0	1
OXYTR SP	0.190	0	1	OXY JORU	-0.010	0	1	OXY NIGR	-0.090	0	1
TOF PUSI	-0.275	0	2	LYC SELA	-0.010	0	1	BOT LUNA	0.010	0	1
PAP KEEL	-0.010	0	1	PIC GLAU	-0.010	0	2	POL VIVI	-0.010	0	1
PYR ASAR	-0.010	0	4	PYR SECU	-0.010	0	1	THA ALPI	-0.315	0	2
POT BIFL	6.190	0	1	SAL ALAX	-0.010	0	1	SAL POLA	0.010	0	1
SAL A XP	-0.010	0	1	SAL RETI	-0.010	0	1	SAX HIRC	-0.010	0	1
SAX OPPO	-0.750	0	1	PED CAPI	-2.493	0	3	PED LANA	-0.010	0	1
PED ARCT	-0.040	0	1	ALE OCHR	-5.475	0	4	ASA CHRY	-0.600	0	2
CET CUCU	-2.257	0	4	CET ERIC	-0.010	0	1	CET ISLA	-1.575	0	4
CET LAEV	-0.500	0	1	CET NIVA	-0.710	0	4	CET PINA	-0.010	0	2
CET RICH	-0.250	0	2	CET TILE	-0.817	0	4	CLA ARBU	-0.130	0	3
CLA RANG	-0.800	0	1	CLA STEL	-0.650	0	2	CLA ACUM	-0.010	0	1
CLA G GR	-0.010	0	1	CLA PUCI	-0.337	0	4	CLA UNCI	-0.340	0	1
COR DIVE	-0.010	0	1	DAC ARCT	-1.062	0	5	DAC RAMU	-0.050	0	2
LEC EPIB	-0.647	0	3	LEC URCE	-1.920	0	2	OCH ULIG	-1.920	0	2
PEL APHT	-0.010	0	1	PEL CANI	-0.010	0	1	POL SENO	-1.460	0	1
SOL BISP	-0.090	0	3	THA SUBU	-1.177	0	4	SOIL LIC	-1.100	0	1
SAX LICH	-0.250	0	1	RIN ROST	-0.800	0	1	VER MURA	0.0	0	1
LEC STIG	-0.093	0	3	HEPATICS	0.0	0	2	ENCALYPT	0.0	0	1
CAM STEL	0.0	0	1	CER PURP	0.0	0	1	CRY HYME	0.010	0	2
DITRICHA	0.0	0	1	DIT FLEX	-0.010	0	2	DREPANOC	-0.010	0	1
DRE REVO	0.010	0	1	HYL SPLE	-0.010	0	2	HYPNUM	0.0	0	1
HYP BAMB	-0.005	0	2	HYP PROC	-0.010	0	1	HYP REVO	0.0	0	1
ORT CRYS	-0.010	0	1	POL STRI	0.0	0	1	RHA LANU	0.007	0	3
RHY RUGO	-0.007	0	3	TOM NITE	-0.003	0	3	TOR ARCT	-0.005	0	2
TOR FRAG	-0.010	0	2	TOR TORT	0.0	0	1	SCHISTIO	0.0	0	1
ENC ALPI	0.0	0	1	FIS OSMU	-0.010	0	2				

J.4 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.) In *Dryas integrifolia*-*Cassiope tetragona* Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
SIL ACAU	0.250	1	0	ANT ARCT	0.250	1	0	RHO INIE	0.250	1	0
GRAMINEA	0.250	1	0	POT FRUT	0.350	1	0	SAL ALAX	0.250	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
OTHR VAS	-10.500	0	1	CAS TETR	-50.440	0	1	DRY OCTO	-31.000	0	1
MIS LICH	-3.970	0	1	MOSS SPP	-5.150	0	1				

J.5 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.) In *Dryas integrifolia*-*Cassiope tetragona* Tundra (n=6)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
OTHR VAS	0.250	1	0	CER BEER	0.010	1	0	MEL APET	0.005	3	1
MIN ARCT	-0.090	5	3	MIN MACR	0.140	1	0	MIN R EL	0.090	5	2
MIN ROSS	0.010	1	0	MIN RUBE	0.010	1	0	SIL ACAU	1.095	3	1
STE LONG	0.040	1	0	STE MONA	0.010	1	0	ANT DENS	0.010	1	0
ARN ALPI	0.167	4	1	CHR INTE	0.140	1	0	SEN ATRO	-0.030	1	1
SEN CYMB	-0.085	2	1	SOL MULT	0.0	1	1	BRA PURP	0.020	3	1
BRA RICH	0.300	1	1	CAR BELL	0.030	1	1	DRA CORY	0.045	3	1
DRA LACT	0.010	1	0	PAR NUDI	0.0	3	3	CAREX SP	0.040	1	0
CAR CAPI	0.0	1	1	CAR GLAC	-0.400	3	1	CAR MICH	0.010	1	0
CAR MISA	0.080	1	1	CAR PETR	-3.110	1	1	CAR RUPE	0.340	1	0
CAR SCIR	-3.162	4	4	KOB SIMP	0.035	2	1	ARC ALPI	0.0	1	1
RHO LAPP	-4.330	1	1	VAC ULIG	-14.530	1	1	VAC VITI	0.010	1	0
GEN PROP	0.040	1	0	ARC LATI	0.010	1	0	CAL PURP	0.010	1	0
OLS CAFS	0.010	1	0	FES ALTA	0.003	3	2	FES BRAC	0.010	1	0
HIE ALPI	0.075	3	0	POA ALPN	0.040	1	0	IRS SPIC	0.070	3	0
JUN BALT	0.040	1	0	LUZ NIVA	0.150	1	1	HED MACK	-0.375	3	1
OXYTR SP	0.0	1	1	LLO SERO	0.030	4	0	TOF PUSI	-0.190	2	2
EPI LATI	1.525	3	0	PAP KEEL	0.0	3	3	ARM MARI	0.010	1	0
OXY DIGY	0.010	1	0	POL BIST	-0.790	1	1	POL VIVI	-0.024	5	5
AND CHAM	-0.293	6	4	ANE PARV	-0.127	4	2	THA ALPI	-0.333	3	3
DRY INTE	-31.380	6	6	DRY OCTO	0.010	1	0	POT BIFL	-3.100	1	1
POT FRUT	0.[illegible]07	3	1	ROS ACIC	0.010	1	0	POP BALS	0.010	1	0
SAL ALAX	4.173	6	2	SAL ARCT	-0.075	2	1	SAL DODG	-0.305	2	3
SAL PLAN	0.010	1	0	SAL POLA	0.005	3	1	SAL A XP	0.0	1	1
SAL RETI	-1.563	3	3	PAR KOTZ	0.010	1	0	PAR PALU	0.010	1	0
SAX AIZO	1.402	4	1	SAX HIER	0.010	1	0	SAX OPPO	-1.130	5	4
PED CAPI	0.080	1	1	PED LANA	0.065	2	2	PED ARCT	0.010	1	0
PED SUDE	0.030	1	1	IER ALGA	0.090	3	0	CET CUCU	-3.010	2	3
CET LAEV	0.490	1	1	CET NIVA	-9.790	3	3	CET TILE	-1.040	1	1
DAC BERI	0.010	1	0	PEL CANI	0.115	2	0	POL SEND	0.0	1	0
THA SUBU	[illegible].660	1	1	SOIL LIC	4.585	3	3	SAX LICH	-2.520	3	2
LEC JURA	0.0	1	0	POLYB SP	0.700	1	0	HEPATICS	0.0	1	0
MOSS SPP	4.308	5	5	ABI ABIE	0.0	1	0	CAM STEL	0.0	1	0
DIT FLEX	0.010	1	1	ORE REVO	0.010	1	1	FUN HYGR	0.0	1	0
HYP BAMB	0.010	1	1	POG ALPI	0.010	1	0	TET MNIO	0.0	1	0
TET PARA	0.0	1	0	TOM NITE	-0.010	1	1	TOR FRAG	0.0	1	0
TOR TORT	0.005	3	0								

J.5 continued

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF.	DISTB.	CONTR	SPECIES	COV.DIF	DISTB	CONTR
BET GLAN	-0.720	0	3	MIN ROSS	-0.265	0	2	SIL ACAU	-1.990	0	4
ANT DENS	-0.040	0	1	CHR INTE	-0.025	0	2	SAU ANGU	-0.075	0	3
PAR NUDI	-0.010	0	3	CAR ATFU	-0.750	0	1	CAR MEMB	-0.010	0	2
CAR MISA	-3.460	0	1	CAR NARD	-1.260	0	1	CAR PETR	-0.345	0	2
CAR PODO	-14.500	0	1	CAR RUPE	-6.335	0	4	CAR SCIR	-3.560	0	2
CAR VAGI	-0.010	0	1	ERI ANGU	-5.882	0	4	ERI CALL	-0.350	0	1
KOB MYOS	-0.010	0	1	KOB SIMP	-0.875	0	2	EMP NIGR	-0.010	0	1
AND POLI	-0.373	0	3	ARC ALPI	-3.835	0	2	CAS TETR	-6.568	0	5
LLO GRDE	-0.010	0	1	RHO LAPP	-0.373	0	3	VAC ULIG	-0.010	0	3
ARC LATI	-0.140	0	1	ELY INNO	-0.010	0	1	JUN BIGL	-0.010	0	1
JUN ALBE	-0.200	0	2	LUZ PARV	-0.010	0	1	TRI MARI	-0.010	0	1
HEO ALPI	-0.350	0	1	OXYTR SP	-0.190	0	1	OXY NIGR	-0.090	0	1
OXY SHEL	-0.010	0	1	PIN VULG	-0.010	0	3	LLO SERO	-0.010	0	1
TOF PUSI	-0.550	0	3	LYC SELA	-0.010	0	1	BOT LUNA	-0.010	0	1
PIC GLAU	-0.010	0	1	POL VIVI	-0.040	0	1	PYR ASAR	-0.010	0	3
PYR SECU	-0.010	0	1	ANE PARV	-0.040	0	1	THA ALPI	-0.357	0	3
DRY OCTO	-1.870	0	1	POT BIFL	-3.470	0	3	POT FRUT	-0.010	0	2
SAL ARCT	-0.010	0	1	SAL POLA	-0.010	0	1	SAL RETI	-1.517	0	3
SAX HIRC	-0.010	0	1	PED CAPI	-0.230	0	3	PED LANA	-0.010	0	2
PED SUDE	-0.053	0	3	ALE OCHR	-3.702	0	4	ASA CHRY	-0.600	0	1
CET CUCU	5.680	0	3	CET DELI	-0.685	0	2	CET ERIC	-1.810	0	3
CET ISLA	-3.363	0	3	CET NIVA	-0.303	0	4	CET PINA	-0.010	0	1
CET RICH	-0.575	0	2	CET TILE	-3.946	0	5	CLA ARBU	-1.170	0	3
CLA RANG	-0.800	0	1	CLA STEL	-0.650	0	1	CEADO SP	-0.010	0	1
CLA ACUM	-0.010	0	1	CLA CHLO	0.0	0	1	CLA G GR	-0.190	0	1
CLA MAJO	0.0	0	1	CLA PHYL	0.0	0	1	CLA POCI	-0.167	0	4
CLA PYXI	-0.130	0	3	CLA UNCI	-0.340	0	1	CLAD SPP	-0.340	0	1
COR ACUL	-0.010	0	1	COR DIVE	-0.010	0	1	DAC ARCT	-0.715	0	4
DAC BERI	-0.440	0	1	DAC RAMU	-0.037	0	3	LEC EPIB	-0.530	0	3
LEC URCE	-1.315	0	2	OCH ULTG	-1.930	0	1	PEL APHT	-0.010	0	1
PEL CANI	0.010	0	2	SOL BISP	-0.055	0	6	THA SUBU	-2.455	0	4
THA VERM	-0.010	0	1	SOIL LIC	-1.130	0	3	SAX LICH	-9.540	0	2
RIN ROSI	-0.800	0	1	VER MURA	0.0	0	1	LEC STIG	-0.047	0	3
POL INTE	0.0	0	1	HEPATICS	-0.003	0	3	MOSS SPP	-0.340	0	1
AUL ACUM	0.0	0	1	ENCALYPT	0.0	0	1	CER PURP	0.0	0	1
CIR CIRR	0.010	0	1	CRY HYME	-0.010	0	1	DITRICHA	0.0	0	1
DIT FLEX	-0.010	0	1	DREPANOC	-0.010	0	1	HYL SPLE	-0.010	0	2
HYPNUM	-0.005	0	3	HYP BAMB	-0.008	0	5	HYP PROC	-0.010	0	1
HYP REVO	0.0	0	1	MYU JULA	-0.010	0	1	ORT CRYS	-0.010	0	1
POL STRI	0.0	0	1	RHA LANU	-0.005	0	2	RHY RUGO	-0.003	0	3
TOM NITE	0.0	0	3	TOR ARCT	-0.010	0	1	TOR FRAG	-0.010	0	1
TOR TORT	0.0	0	3	LNC ALPI	0.0	0	1	FIS OSMU	-0.010	0	1

J.6 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.) In *Dryas integrifolia-Cassiope tetragona* Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0.0	1	1	MIN ARCT	0.010	1	0	MIN R EL	-0.050	2	2
SIL ACAU	-1.350	1	1	ANT DENS	0.010	1	0	ARN ALPI	0.140	1	0
AST SIBI	0.010	1	0	SEN CYMB	0.440	1	0	SOL MULT	0.010	1	0
BRA PURP	0.250	1	0	CAR AIFU	-0.740	1	1	CAR CAPI	0.080	1	1
CAR GLAC	1.560	1	0	CAR MEMB	0.010	1	0	CAR PETR	-2.550	1	1
CAR SCIR	1.640	2	2	KOB MYOS	0.640	1	1	KOB SIMP	-0.790	1	1
EMP NIGR	0.010	1	0	EQU PALU	0.010	1	0	EQU VARI	0.010	1	0
ARC ALPI	0.0	2	2	LEO GROE	0.0	1	1	RHO LAPP	-4.330	1	1
AGP VIOL	0.010	1	0	DES CAES	0.010	1	0	ELY INNO	0.010	2	0
POA ALPN	0.010	1	0	IRS SPIC	0.090	2	0	HED MACK	-1.250	1	1
LLO SERO	0.090	1	0	TOF PUSI	0.0	1	1	HAB HYPE	0.010	1	0
ARM MARI	0.010	1	0	POL VIVI	0.265	2	2	AND CHAM	1.185	2	0
PYR ASAR	0.0	1	1	ANE PARV	0.005	2	1	THA ALPI	-0.250	1	1
DRY INTE	-28.335	2	2	POT FRUT	0.135	2	1	POP BALS	0.305	2	0
SAL ALAX	21.265	2	1	SAL ARBU	0.010	2	0	SAL ARCT	-0.240	1	1
SAL RETI	-2.260	2	2	PAR PALU	0.010	1	0	SAX AIZO	0.540	2	1
SAX OPPO	5.440	2	1	PED LANA	0.0	1	1	TER ALGA	0.290	1	0
CET NIVA	-1.090	1	1	CET TILE	-1.040	1	1	SOIL LIC	-0.865	2	2
MOSS SPP	-15.900	1	1								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
CAR PETR	-0.500	0	1	CAR RUPE	-18.000	0	1	CAR VAGI	-0.010	0	1
ERI ANGU	-23.500	0	-1	ERI CALL	0.250	0	1	KOB SIMP	-0.190	0	1
AND POLI	0.010	0	1	CAS TETR	0.800	0	1	RHO LAPP	-0.800	0	1
VAC ULIG	-0.010	0	1	ARC LATI	0.140	0	1	FES ALTA	-0.010	0	1
JUN ALBE	-0.390	0	1	TRI MARI	0.010	0	1	HED ALPI	-0.250	0	1
OXYTR SP	-0.190	0	1	OXY NIGR	-0.090	0	1	PIN VULG	-0.010	0	2
TOF PUSI	-0.540	0	1	PIC GLAU	-0.010	0	1	THA ALPI	-0.440	0	1
POT BIFL	-6.190	0	1	SAX HIRC	-0.010	0	1	PED CAPI	-0.340	0	2
PED LANA	0.010	0	1	PED SUDE	-0.010	0	1	ALE OCHR	-3.555	0	2
ASA CHRY	-0.600	0	1	CET CUCU	-10.665	0	2	CET ISLA	-4.950	0	2
CET NIVA	-0.010	0	1	CET PINA	-0.010	0	1	CET RICH	-0.250	0	1
CET TILE	-0.010	0	1	CLA ARBU	-1.750	0	2	CLA STEL	-0.650	0	1
CLA CHLO	0.0	0	1	CLA G GR	-0.190	0	1	CLA MAJO	0.0	0	1
CLA PHYL	0.0	0	1	CLA POCI	-0.325	0	2	CLAO SPP	-0.340	0	1
DAC ARCT	-1.560	0	1	LEC EPIB	-0.040	0	1	LEC URCE	-1.920	0	1
OCH ULIG	-1.920	0	1	SOL BISP	-0.010	0	2	THA SUBU	-1.660	0	1
VER MURA	0.0	0	1	LEC STIG	-0.140	0	1	MOSS SPP	-0.390	0	1
AUL ACUM	0.0	0	1	CIR CIRR	-0.010	0	1	CRY HYME	-0.010	0	1
DIT FLEX	-0.010	0	1	HYL SPLE	-0.010	0	1	HYP BAMB	-0.010	0	2
MYU JULA	-0.010	0	1	RHA LANU	-0.010	0	1	RHY RUGO	-0.005	0	2
TOM NITE	0.0	0	1	TOR FRAG	0.010	0	1	FIS OSMU	-0.010	0	1

J.7 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.) In *Dryas integrifolia-Cassiope tetragona* Tundra (n=5)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR.	SPECIES	COV DIF.	DISTB	CONTR
MIN R EL	-0.137	3	3	ANT DENS	0.010	2	0	CHR INTE	0.010	1	0
SEN CYMB	-0.180	1	1	SOL MULT	0.010	1	0	DRA CORY	0.0	1	1
CAR A ST	7.050	1	0	CAR CAPI	0.010	1	0	CAR GLAC	0.635	2	0
CAR MEMB	20.630	4	0	CAR MISA	0.010	1	0	CAR PETR	-3.140	1	1
CAR RUPE	-17.990	1	1	CAR SCIR	-3.150	3	3	ERI ANGU	0.380	2	0
ERI CALL	0.010	1	0	KOB MYOS	0.305	2	0	KOB SIMP	-0.180	2	2
EQU SCIR	0.010	2	0	ARC ALPI	0.0	2	2	CAS TETR	-0.790	1	1
RHO LAPP	-0.790	2	2	ARC LATI	0.010	2	0	ELY INNO	0.010	3	0
FES ALIA	0.590	1	1	POA SP	0.010	1	0	POA ALPN	0.305	2	0
IRS SPIC	0.075	2	0	JUN BALT	0.682	4	0	JUN CAST	0.010	2	0
JUN ALBE	0.010	2	0	HED MACK	-1.250	1	1	PIN VULG	0.0	1	1
TOF PUSI	-0.530	2	2	POL VIVI	-0.608	5	5	AND CHAM	0.650	4	0
ANE PARV	0.015	2	2	THA ALPI	0.242	4	4	DRY INTE	-39.490	4	4
POT BIFL	-6.180	1	1	PUT FRUT	0.0	2	2	POP BALS	0.010	2	0
SAL ALAX	0.090	3	3	SAL ARBU	0.010	2	0	SAL ARCT	-2.310	2	1
SAL RETI	0.0	3	3	PED SUDE	0.010	1	0	CET CUCU	-4.430	1	1
CET DELI	0.010	1	0	CET TILE	-1.040	1	1	CLA POCI	-0.640	1	1
LEC EPIB	0.010	1	0	THA SUBU	-1.650	2	2	SOIL LIC	5.950	1	1
MOSS SPP	-0.245	2	2	BRYUM SP	0.010	1	0	CAM STEL	0.010	1	0
HYP BAMB	0.0	1	1	POL JUNI	0.010	1	0	TOM NITE	0.010	1	0
TOR ARCT	0.010	1	0	TOR FRAG	0.0	1	1	TOR TORT	0.010	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-0.010	0	4	MEL APET	-0.010	0	1	MIN ARCT	-0.440	0	1
MIN R EL	-0.140	0	2	SIL ACAU	-1.638	0	5	ARN ALPI	-0.750	0	1
CHR INTE	-0.040	0	1	SAU ANGU	-0.010	0	1	SEN AIRO	-0.010	0	1
SEN LUGE	-0.010	0	1	CAR ATFU	-0.010	0	1	CAR MEMB	-0.010	0	1
CAR MISA	-0.440	0	1	CAR PETR	-3.150	0	3	CAR RUPE	-18.000	0	3
CAR SCIR	-2.510	0	2	ERI ANGU	-0.010	0	1	KOB SIMP	-0.680	0	3
EQU VARI	-0.910	0	2	AND POLI	-0.010	0	4	ARC ALPI	-0.010	0	2
CAS TETR	-0.602	0	4	LEO GROE	-0.010	0	4	RHO LAPP	-0.800	0	2
VAC ULIG	-0.010	0	4	GEN PROP	-0.010	0	1	FES ALTA	-0.010	0	3
IRS SPIC	0.010	0	1	JUN BIGL	-0.010	0	1	JUN ALBE	-0.140	0	1
LUZ NIVA	-0.010	0	1	AST UMBE	-0.010	0	1	HED ALPI	-0.202	0	5
HED MACK	-1.260	0	3	OXYTR SP	-0.190	0	4	OXY JORD	-0.010	0	1
OXY NIGR	0.090	0	4	PIN VULG	-0.010	0	3	TOF PUSI	-0.363	0	3
PAP KIEL	-0.040	0	1	PIC GLAU	-0.010	0	4	ARM MARI	-0.010	0	1
POL BIST	-0.140	0	1	AND CHAM	-0.010	0	1	PYR ASAR	-0.010	0	8
ANE PARV	-0.020	0	3	THA ALPI	-0.540	0	1	DRY INTE	-34.500	0	1
POT BIFL	-5.470	0	4	POT FRUT	-0.010	0	2	SAL ALAX	-0.010	0	1
SAL A XP	-0.010	0	1	SAL RETI	-0.355	0	2	SAX AIZO	-0.010	0	5
SAX HIRC	-0.010	0	1	SAX OPPO	-0.602	0	5	PED CAPI	-1.612	0	5
PED LANA	-0.010	0	4	PED ARCT	-0.040	0	1	PED SUDE	-0.010	0	1
ALE OCHR	-5.682	0	5	ASA CHRY	-0.600	0	4	CET CUCU	-3.332	0	4
CET ERIC	-0.010	0	1	CET ISLA	-2.442	0	5	CET NIVA	-0.908	0	5
CET PINA	-0.010	0	4	CET RICH	-0.208	0	5	CET TILE	-0.790	0	4
CLA ARBU	-0.154	0	5	CLA STEL	-0.650	0	4	CLA G GR	-0.010	0	1
CLA POCI	-0.497	0	4	DAC ARCT	-1.428	0	5	LEC EPIB	-0.390	0	1
LEC URCE	-1.920	0	4	OCH ULIG	-1.920	0	4	POL SEND	-1.460	0	1
SOL BISP	-0.026	0	5	THA SUBU	-1.110	0	3	SOIL LIC	-1.100	0	3
VER MURA	0.0	0	4	LEC STIG	-0.140	0	4	MOSS SPP	-2.610	0	3
CAM STEL	0.0	0	1	CRY HYME	-0.010	0	4	DIT FLEX	-0.010	0	4
HYL SPLE	-0.010	0	4	HYP BAMB	-0.008	0	4	RHA LANU	-0.010	0	4
RHY RUGO	-0.010	0	4	TOM NITE	0.0	0	1	TOR ARCT	0.0	0	1
TOR FRAG	0.010	0	3	SCHISTIO	0.0	0	1	FIS OSMU	-0.010	0	4

K.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In *Dryas integrifolia-Carex* Species Tundra (n=3)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ARE HUMI	0.010	1	0	MIN ARCT	-0.030	1	1	MIN R EL	-0.050	1	1
MIN ROSS	0.130	1	1	SIL ACAU	0.010	1	0	ANT OENS	0.0	1	1
ARN ALPI	0.010	1	0	CHR INTE	-0.130	1	1	SUL MULT	0.010	2	0
BRA PURP	0.045	2	1	DRA CORY	0.0	1	1	PAR NUDI	0.0	2	2
CAR GLAC	0.010	1	0	CAR MISA	-0.890	1	1	SHE CANA	2.700	1	0
ARC ALPI	-3.460	2	2	ELY INNO	0.010	1	0	POA ALPN	0.010	1	0
TRS SPIC	0.010	1	0	JUN ALBE	-0.240	1	1	HED ALPI	0.100	1	1
OXYTR SP	0.190	1	0	TOF CUCC	0.010	1	0	TOF PUSI	-0.200	1	1
ZYG ELEG	-0.740	1	1	EPI LATI	0.035	2	1	PAP KEEL	0.0	1	1
POL VIVI	-0.105	2	2	AND CHAM	-0.240	1	1	PYR SECU	0.600	1	0
ANE PARV	0.840	1	1	THA ALPI	-0.240	1	1	DRY INTE	-22.653	3	3
POT FRUT	-3.170	2	2	POP BALS	0.010	2	0	SAL ALAX	3.097	3	0
SAL ARBU	0.010	1	0	SAL ARCT	-0.090	2	2	SAL DODG	-0.180	1	1
SAL GLAU	0.010	1	0	SAL POLA	0.0	1	1	SAL RETI	0.005	2	1
SAX AIZO	-0.995	2	2	SAX OPPO	-1.567	3	3	DAC RAMU	0.010	1	0
PEL RUFE	0.025	2	0	MOSS SPP	1.570	2	2				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ARCT	-0.340	0	1	SIL ACAU	-0.600	0	1	ARN ALPI	-0.010	0	1
CHR INTE	-0.505	0	2	SEN ATRO	-0.010	0	1	SEN CYMB	-0.140	0	1
CAREX SP	-15.000	0	1	CAR AIFU	-0.010	0	1	CAR CAPI	-0.540	0	1
CAR MEMB	-0.050	0	2	CAR MICG	-0.010	0	1	CAR MISA	3.050	0	1
CAR PODO	-0.700	0	1	CAR RUPE	-7.000	0	1	CAR SCIR	-0.700	0	2
ERI ANGU	-0.500	0	1	KOB SIMP	-2.255	0	2	SCI CAES	-1.560	0	1
EQU VARI	-0.010	0	1	CAS TETR	-0.010	0	2	RHO LAPP	0.340	0	1
POA SP	-0.040	0	1	LYCOP SP	-0.540	0	1	JUNCUS	0.140	0	1
JUN BIGL	-0.100	0	2	PIN VULG	-0.830	0	2	LLO SERO	0.010	0	2
TOF PUSI	-1.560	0	1	POL VIVI	-0.090	0	1	WOO GLAB	0.010	0	1
AND CHAM	-0.365	0	2	ANE PARV	-0.440	0	1	THA ALPI	0.605	0	2
SAL DODG	-0.140	0	1	SAL A XP	-0.040	0	1	SAL RETI	0.250	0	1
PAR FIMB	-0.010	0	1	PED CAPI	-0.800	0	2	PED LANA	0.090	0	1
SEL SELA	0.010	0	1	MIS LICH	-25.500	0	1	CET CUCU	-0.800	0	1
CET TILE	-0.075	0	2	CLA POCI	-0.010	0	1	DAC RAMU	0.0	0	1
THA SUBU	-0.440	0	1	CRUSTOSE	-0.090	0	1	SOIL LIC	-1.410	0	1
SAX LICH	-3.000	0	1	MOSS SPP	-0.090	0	1	BLE TRIC	0.0	0	1
CAT NIGR	0.0	0	1	DIT FLEX	0.0	0	1	HYP BAMB	0.005	0	2
TOR RURA	0.0	0	1	CIN STYG	0.0	0	1				

K.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In *Dryas integrifolia-Carex* Species Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MEL APET	0.010	1	0	AST SIBI	0.010	1	0	CHR INTE	-0.990	1	1
SAU ANGU	0.010	1	0	SEN CYMB	0.010	1	0	BRA PURP	0.250	1	0
CAR CAPI	0.010	1	0	CAR MEMB	2.140	1	0	CAR SCIR	2.140	1	0
EQU ARVE	0.010	1	0	ARC ALPI	-6.330	1	1	DES CAES	0.040	1	0
JUN ALBE	0.010	1	0	HED ALPI	-0.590	1	1	POL VIVI	-0.080	1	1
AND CHAM	0.530	1	1	ANE PARV	-0.350	1	1	THA ALPI	-3.240	1	1
DRY INTE	-23.410	1	1	POT FRUT	-5.550	1	1	SAL ALAX	0.600	1	0
SAL PLAN	2.140	1	0	SAL RETI	-0.240	1	1	SAX AIZO	0.200	1	1
SAX OPPO	3.470	1	1	MIS LICH	-25.250	1	1	MOSS SPP	-0.910	1	1
DIT FLEX	0.0	1	1								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
SIL ACAU	0.600	0	1	ARN ALPI	-0.010	0	1	CAREX SP	-15.000	0	1
CAS TETR	0.010	0	1	LYCOP SP	-0.540	0	1	JUNCUS	0.140	0	1
PIN VULG	-1.410	0	1	LLO SERO	0.010	0	1	TOF PUSI	-1.560	0	1
ZYG ELEG	-0.750	0	1	PAR FIMB	0.010	0	1	PED CAPI	0.190	0	1
SEL SELA	-0.010	0	1	CET TILE	-0.010	0	1	CLA POCI	0.010	0	1
BLE TRIC	0.0	0	1	HYP BAMB	0.0	0	1	TOR RURA	0.0	0	1

K.3 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In *Dryas integrifolia-Carex* Species Tundra (n=3)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ARE HUMI	0.010	1	0	MIN ARCT	-0.030	1	1	MIN R EL	0.600	1	0
SIL ACAU	0.010	1	0	ARN ALPI	0.005	2	1	CHR INTE	-0.495	2	2
CRE NANA	0.010	1	0	SEN CYMB	-0.130	1	1	BRA PURP	0.005	2	1
BRA RICH	0.010	1	0	DRA CORY	0.0	1	1	LES ARCT	0.010	1	0
PAR NUDI	0.0	2	2	SME BORE	0.010	1	0	CAR GLAC	0.010	1	0
CAR RUPE	-6.960	1	1	CAR SCIR	-0.457	3	2	ARC ALPI	-6.330	1	1
RHO LAPP	-0.330	1	1	POA SP	-0.030	1	1	TRS SPIC	0.010	1	0
JUN ALBE	-0.240	1	1	HED ALPI	-0.275	2	1	OXY JORO	0.010	1	0
LLO SERO	0.005	2	1	TOF COCC	0.010	1	0	TOF PUSI	-0.380	1	1
EPI LATI	0.300	2	1	PAP KEEL	0.020	2	1	POL VIVI	-0.097	3	3
AND CHAM	0.210	2	2	ANE PARV	-0.635	2	2	THA ALPI	-1.190	1	1
DRY DRUM	0.010	1	0	DRY INTE	-28.697	4	4	POT FRUT	-3.170	2	2
POP BALS	0.010	1	0	SAL ALAX	1.170	3	0	SAL ARBU	0.010	2	0
SAL DODG	-0.155	2	2	SAL POLA	0.0	1	1	SAL A XP	-0.030	1	1
SAL RETI	0.005	2	1	SAX AIZO	-0.980	2	2	SAX OPPO	-1.233	3	3
PED LANA	-0.035	2	1	CET CUCU	0.010	1	0	CET TILE	-0.060	2	1
DAC RAMU	0.010	1	0	LEC EPIB	0.010	1	0	SOL BISP	0.010	1	0
THA SUBU	0.010	1	0	SOIL LIC	-0.610	1	1	SAX LICH	-2.660	1	1
MOSS SPP	-0.710	2	2								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ARCT	-0.340	0	1	MIN R EL	-0.190	0	1	MIN ROSS	-0.010	0	1
SIL ACAU	0.600	0	1	ANT OENS	-0.010	0	1	CHR INTE	-0.140	0	1
SEN ATRO	0.010	0	1	CAREX SP	-15.000	0	1	CAR AIFU	-0.010	0	1
CAR CAPI	-0.540	0	1	CAR MEMB	-0.050	0	2	CAR MICG	-0.010	0	1
CAR MISA	-1.975	0	2	CAR PODO	-0.700	0	1	ERI ANGU	-0.500	0	1
KOB SIMP	-2.255	0	2	SCI CAES	-1.560	0	1	EQU VARI	-0.010	0	1
ARC ALPI	-0.600	0	1	CAS TETR	-0.010	0	2	LYCOP SP	-0.540	0	1
JUNCUS	-0.140	0	1	JUN BIGL	-0.100	0	2	PIN VULG	-0.830	0	2
LLO SERO	-0.010	0	1	TOF PUSI	-1.560	0	1	ZYG ELEG	-0.750	0	1
WOO GLAB	-0.010	0	1	AND CHAM	-0.540	0	1	THA ALPI	-0.130	0	2
SAL ARCT	-0.100	0	2	SAL RETI	-0.250	0	1	PAR FIMB	-0.010	0	1
PED CAPI	-0.800	0	2	SEL SELA	-0.010	0	1	MIS LICH	-25.500	0	1
CET CUCU	-0.800	0	1	CET TILE	-0.010	0	1	CLA POCI	-0.010	0	1
DAC RAMU	0.0	0	1	THA SUBU	-0.440	0	1	CRUSTOSE	-0.090	0	1
MOSS SPP	-0.090	0	1	BLE TRIC	0.0	0	1	CAT NIGR	0.0	0	1
DIT FLEX	0.0	0	1	HYP BAMB	-0.005	0	2	TOR RURA	0.0	0	1
CIN STYG	0.0	0	1								

K.4 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.)

In *Dryas integrifolia-Carex* Species Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ARE HUMI	0.010	1	0	MIN R EL	0.010	1	0	DRA CORY	0.0	1	1
PAR NUDI	0.0	1	1	CAR MISA	-0.890	1	1	CAR RUPE	-6.990	1	1
CAR SCIR	-0.890	1	1	AND CHAM	-0.240	1	1	DRY INTE	-26.990	1	1
SAL ALAX	0.010	1	0	SAL DODG	-0.180	1	1	SAL A XP	-0.030	1	1
SAL RETI	0.0	1	1								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ARCT	-0.040	0	1	MIN ROSS	-0.010	0	1	CHR INTE	-0.010	0	1
SEN ATRO	-0.010	0	1	SEN CYMB	-0.140	0	1	CAR MEMB	-0.090	0	1
ERI ANGU	-0.500	0	1	KOB SIMP	-0.010	0	1	EQU VARI	-0.010	0	1
CAS TETR	0.010	0	1	POA SP	-0.040	0	1	JUN BIGL	-0.190	0	1
PAP KEEL	0.010	0	1	POL VIVI	-0.040	0	1	WOO GLAB	-0.010	0	1
THA ALPI	-0.010	0	1	SAL ARCT	-0.010	0	1	SAL POLA	-0.010	0	1
SAX OPPO	-0.900	0	1	PED LANA	-0.090	0	1	CET CUCU	-0.800	0	1
CET TILE	-0.140	0	1	DAC RAMU	0.0	0	1	THA SUBU	-0.440	0	1
SOIL LIC	-1.410	0	1	SAX LICH	-3.000	0	1	MOSS SPP	-0.090	0	1
HYP BAMB	0.010	0	1								

L.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Cetraria tilesii Tundra (n=7)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	4.075	2	2					ARE HUMI	0.250	1	0
MEL APET	0.050	3	1	MIN ARCT	-0.020	4	4	MIN R EL	0.790	5	3
SIL ACAU	-1.157	6	5	STE EDWA	0.010	1	0	SIE LAEI	0.0	1	1
ANT DENS	0.405	2	2	ANT EKMA	-0.030	1	1	ARN ALPI	0.253	3	1
AST SIBI	0.010	1	0	CHR INTE	0.003	3	2	SEN CYMB	0.213	3	2
SOL MULT	0.040	1	0	BRA PURP	0.047	3	2	DRA CORY	0.0	1	1
DRA OGIL	0.010	1	0	PAR NUDI	0.023	3	2	CAR ATFU	0.0	1	1
CAR CAPI	0.010	1	0	CAR GLAC	-0.940	3	1	CAR MEMB	24.385	4	0
CAR MISA	0.900	1	0	CAR PETR	-12.530	1	1	CAR SCIR	-2.590	4	4
ERI SCHE	0.010	1	0	ERI VAGI	0.540	1	0	KOB SIMP	0.005	2	1
EMP NIGR	0.010	1	0	EQU ARVE	0.010	2	0	EQU SCIR	0.010	2	0
EQU VARI	-0.085	2	1	ARC ALPI	-0.187	3	3	ARC OVA-	0.010	1	0
RHO LAPP	-1.250	1	1	ARC LATI	0.010	2	0	ELY INNO	0.095	4	2
FES ALTA	0.010	1	0	FES BRAC	0.040	1	0	POA SP	0.010	1	0
TRS SPIC	0.010	1	0	JUN BALT	0.010	3	0	JUN CASI	0.010	1	0
JUN ALBE	0.037	3	0	HED MACK	-0.385	2	2	OXY JORO	0.0	1	1
PIN VULG	0.0	1	1	TOF COCC	0.180	3	2	TOF PUSI	0.220	4	4
EPI LATI	0.010	2	0	PAP KEEL	-0.010	2	1	PIC GLAU	0.010	1	0
ARM MARI	0.010	2	0	POL VIVI	-0.050	5	4	AND CHAM	-0.397	6	6
PRI EGAL	0.010	1	0	ANE PARV	0.040	4	1	THA ALPI	-0.225	2	2
DRY ORUM	0.010	1	0	ORY INTE	-9.030	6	6	POT BIFL	0.0	1	1
POT FRUT	0.056	5	4	POP BALS	0.010	1	0	SAL ALAX	8.300	7	0
SAL ARBU	0.233	3	0	SAL ARCT	1.149	7	5	SAL OODO	-0.210	2	1
SAL GLAU	0.053	3	0	SAL PLAN	0.010	1	0	SAL A XP	0.010	1	0
SAL RETI	-0.083	3	3	PAR PALU	0.0	1	1	SAX AIZO	0.020	3	0
SAX OPPO	0.473	6	6	PED CAPI	0.0	1	1	PED LANA	0.043	3	2
PED SUDE	0.115	4	3	BASIDIUM	0.440	1	0	TER ATGA	0.140	1	0
ALE OCHR	0.030	1	1	CET CUCO	-6.010	1	1	CET TILE	7.040	1	1
LEC EPIB	0.660	1	1	SOIL LIC	-2.570	3	2	VER MURA	0.440	1	0
MOSS SPP	-0.270	4	3	BRYUM SP	0.0	1	1	CAM POLY	0.0	1	0
ORE UNCI	0.010	1	0	HYP DAMB	0.0	1	0	TOR ARCT	0.0	1	0
TRI ARCT	0.0	1	0	WEI CONT	0.0	1	0				

---------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0.010	0	3	MIN ARCT	-0.040	0	1	MIN R EL	0.190	0	1
MIN ROSS	-0.190	0	1	SIL ACAU	-3.510	0	1	ANT DENS	-0.010	0	2
ANT EKMA	0.040	0	1	ARN ALPI	-0.010	0	1	CHR INTE	-0.010	0	4
SEN ATRO	-0.010	0	2	SEN CYMB	-0.040	0	1	BRA PURP	-0.010	0	1
BRA RICH	-0.010	0	1	LES ARCT	-0.010	0	1	PAR NUDI	-0.063	0	3
CAREX SP	-0.250	0	1	CAR ATFO	-0.010	0	2	CAR MISA	-0.010	0	1
CAR PETR	-1.540	0	6	CAR RUPE	2.049	0	7	CAR SCIR	-1.877	0	3
KOB SIMP	-0.010	0	1	SCI CAES	-0.010	0	1	EQU VARI	-0.190	0	1
AND POLI	-0.112	0	5	ARC ALPI	-0.030	0	3	CAS TETR	-1.237	0	6
RHO LAPP	-0.916	0	5	VAC ULIG	0.010	0	3	GEN PROP	0.010	0	3
AST UMBE	-0.010	0	2	HED ALPI	-0.010	0	2	HED MACK	-0.010	0	4
OXY JORD	0.170	0	3	PIN VULG	0.145	0	4	LLO SERO	-0.090	0	1
TOF COCC	-0.010	0	3	TOF PUSI	0.040	0	2	ZYG ELEG	0.010	0	1
POL VIVI	0.250	0	2	WOO GLAB	0.010	0	2	AND CHAM	0.090	0	1
THA ALPI	-0.316	0	5	ORY INTE	-10.510	0	1	POT BIFL	-0.010	0	3
POT FRUT	0.010	0	1	SAL RETI	0.010	0	1	PAR PALU	-0.010	0	2
SAX OPPO	-0.340	0	1	PED CAPI	-0.025	0	2	PED LABR	-0.010	0	1
PED LAHA	-0.132	0	4	PED SUDE	0.075	0	2	ALE OCHR	-1.928	0	6
ASA CHRY	0.215	0	4	CET COMM	0.0	0	1	CET COCO	-0.346	0	5
CET ERIC	-0.140	0	1	CET ISLA	-0.776	0	7	CET NIVA	-0.156	0	7
CET RICH	-0.040	0	2	CET TILE	-3.512	0	6	CLA ARBU	-0.555	0	2
CLA STEL	-0.010	0	1	CLA PACI	-0.010	0	1	CLA PYXI	-1.360	0	1
CLA ONCI	-0.013	0	1	DAC ARCT	-0.157	0	3	DAC BERI	-0.190	0	2
DAC RAMU	0.140	0	2	LEC EPIB	-2.580	0	1	OCH ANDR	-1.560	0	1
PER DACT	1.340	0	1	SOL BISP	-0.090	0	1	THA SUBU	-0.653	0	6
THA VERM	1.665	0	1	TON LOBO	-5.560	0	1	CRUSTOSE	-10.780	0	2
SOIL LIC	3.815	0	4	SAX LICH	4.693	0	3	COLLEMA	0.0	0	1
VER MURA	1.360	0	1	POL INIE	-0.233	0	3	POL HOPE	-0.680	0	2
OCHRO SP	0.0	0	1	MOSS SPP	0.157	0	3	BRYUM SP	0.0	0	1
DIT FLEX	0.003	0	4	ORE REVO	0.0	0	1	HYPNUM	0.0	0	2
HYP DAMB	0.005	0	2	ORT CRYS	0.0	0	1	POL JUNI	0.0	0	1
RHY RUGO	0.0	0	1	TOM NITE	0.0	0	2	TOR FRAG	0.010	0	1
TOR TORT	0.0	0	3								

L.2 Cover Differences (Cov.Dif.) Between False Start Roads (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Cetraria tilesii Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN R EL	0.010	1	0	SIL ACAU	-2.890	1	1	ARN LOOI	0.010	1	0
ART ARCT	0.010	1	0	CRE NANA	0.250	1	0	SEN CYMB	0.0	1	1
SOL MULI	0.010	1	0	BRA PORP	0.090	1	0	SME BORE	0.010	1	0
CAR GLAC	1.410	1	0	CAR MISA	0.0	1	1	KOB MYOS	0.010	1	0
ARC ALPI	-0.590	1	1	RHO LAPP	-0.080	1	1	VAC ULIG	0.040	1	0
ELY INNO	0.010	1	0	POA ALPG	0.010	2	0	HED ALPI	8.890	1	1
HED MACK	0.0	1	1	OXY JORO	0.0	1	1	TOF PUSI	0.0	1	1
PIC GLAU	0.010	1	0	POL VIVI	0.0	1	1	WOO GLAB	0.0	1	1
AND CHAM	-0.100	2	2	ANE PARV	0.020	2	1	THA ALPI	-0.095	2	2
ORY ORUM	0.025	2	0	ORY INTE	4.120	2	2	POT FRUT	0.005	2	1
POT UNIF	0.090	1	0	POP BALS	0.010	1	0	SAL ALAX	2.050	2	0
SAL ARBU	0.040	1	0	SAL OODG	0.010	1	0	SAL GLAU	0.090	1	0
SAX AIZO	0.045	2	1	SAX OPPO	0.355	2	2	PED LANA	0.030	1	1
CET TILE	-1.650	1	1								

---------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB	CONTR
BET GLAN	-0.010	0	1	MIN ARCT	-0.010	0	1	ANT DENS	-0.010	0	1
LES ARCT	-0.010	0	2	CAR PETR	-1.670	0	2	CAR RUPE	-0.595	0	2
CAR SCIR	-0.010	0	2	AND POLI	-0.040	0	1	ARC ALPI	-0.010	0	1
CAS TETR	-0.440	0	1	OXY JORO	-0.010	0	1	PIN VULG	-0.190	0	1
TOF COCC	-0.010	0	2	TOF POSI	-0.010	0	1	SAL OOOG	-0.010	0	1
SAL RETI	-0.010	0	1	PED LANA	-0.340	0	1	PED SUDE	-0.010	0	1
ALE OCHR	-0.140	0	1	ASA CHRY	-0.140	0	1	CET COCU	-0.950	0	1
CET ISLA	-0.290	0	1	CET NIVA	-0.290	0	1	CET TILE	-0.090	0	1
CLA ARBU	-0.010	0	1	DAC BERI	-0.090	0	1	DAC RAMU	-0.090	0	1
THA SUBU	-0.145	0	2	CRUSTOSE	-11.060	0	1	SOIL LIC	-5.000	0	1
SAX LICH	-2.580	0	1	POL INIE	0.0	0	1	POL RUPE	0.0	0	1
MOSS SPP	-0.065	0	2	DIT FLEX	0.0	0	1	ORE REVO	0.0	0	1
HYP BAMB	0.0	0	1	ORT CRYS	0.0	0	1	TOR FRAG	0.0	0	1
TOR NORV	0.010	0	1								

L.3 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Cetraria tilesii Tundra (n=3)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-4.090	2	2	MEL APET	0.030	1	1	MIN ARCT	-0.053	3	1
MIN R EL	0.023	3	1	SIL ACAU	-1.345	2	2	STE LAET	0.0	1	1
STE LONG	0.010	1	0	STE MONA	0.010	1	0	ANT OENS	0.145	2	2
ARN ALPI	0.010	1	0	CHR INTE	0.060	3	3	SEN CYMB	0.037	3	1
BRA PURP	0.140	3	3	BRA RICH	0.010	1	0	ORA CORY	-0.030	1	1
LES ARCT	0.040	1	0	PAR NUOI	0.025	2	2	CAR GLAC	0.010	2	0
CAR MISA	0.175	2	0	CAR PETR	-7.320	2	2	CAR RUPE	-2.895	2	2
CAR SCIR	-4.120	2	2	KOB SIMP	0.240	1	1	AND POLI	0.0	1	1
ARC ALPI	0.0	2	2	RHO LAPP	-0.503	3	3	VAC ULIG	0.0	1	1
ELY INNO	0.0	1	1	HEO ALPI	0.0	2	2	HEO MACK	-0.385	2	2
OXY JURO	0.590	1	1	LLO SERO	-0.080	1	1	TOF CUCC	-0.080	1	1
TOF PUSI	0.030	1	1	PAP KEEL	0.0	1	1	POL VIVI	-0.077	3	3
AND CHAM	-0.310	3	3	ANE PARV	0.080	1	1	THA ALPI	-0.210	2	2
DRY INTE	-7.697	3	3	POT FRUT	0.0	2	2	SAL ALAX	0.463	3	0
SAL ARBU	0.010	2	0	SAL ARCT	0.693	3	3	SAL OODG	-0.170	2	1
SAL GLAU	0.010	1	0	SAL RETI	0.0	1	1	PAR PALU	0.0	1	1
SAX AIZO	0.010	1	0	SAX OPPO	0.797	3	3	PED LANA	0.020	2	1
PEO SUDE	-0.130	1	1	TER ALGA	2.120	1	0	CET CUCU	-6.010	1	1
CET TILE	-7.040	1	1	SOL BISP	0.090	1	1	THA SUBU	0.010	1	0
CRUSTOSE	-10.060	1	1	SOIL LIC	2.067	3	2	SAX LICH	4.690	1	0
COLLEMA	0.0	1	1	POL INTE	-0.700	1	1	THE AENE	9.000	1	0
MOSS SPP	0.217	3	2	TUR INCL	0.0	1	0				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ROSS	-0.190	0	1	SIL ACAU	-0.010	0	1	CAREX SP	-0.250	0	1
CAR ATFU	-0.010	0	1	CAR PETR	-3.150	0	1	CAR RUPE	-2.580	0	1
CAR SCIR	-0.090	0	1	KOB SIMP	-0.010	0	1	SCI CAES	-0.010	0	1
AND POLI	-0.010	0	1	ARC ALPI	-0.010	0	1	CAS TETR	-0.053	0	3
PIN VULG	-0.010	0	2	TOF CUCC	-0.140	0	1	TOF PUSI	-0.010	0	1
WOO GLAB	-0.010	0	1	THA ALPI	-0.640	0	1	POT BIFL	-0.010	0	2
SAL RETI	-0.010	0	1	PED CAPI	-0.040	0	1	PEO LABR	-0.010	0	1
PED LANA	0.140	0	1	PED SUDE	-0.090	0	1	ALE OCHR	-3.627	0	3
ASA CHRY	-0.700	0	1	CET COMM	0.0	0	1	CET CUCU	-0.010	0	1
CET ISLA	-1.543	0	3	CET NIVA	-0.090	0	3	CET TILE	-4.205	0	2
CLA ARBU	-1.100	0	1	CLA STEL	-0.010	0	1	CLA POCI	-0.010	0	1
CLA PYXI	-1.360	0	1	DAC ARCT	-0.190	0	1	DAC BERI	-0.290	0	1
LEC EPIB	-1.100	0	1	OCH ANOR	-1.560	0	1	PER DACI	-1.360	0	1
THA SUBU	-0.295	0	2	THA VERM	-1.660	0	1	TON LOBU	5.560	0	1
VER MURA	-1.360	0	1	POL RUPE	-1.360	0	1	OCHRO SP	0.0	0	1
OIT FLEX	-0.010	0	1	HYP BAMB	-0.010	0	1	POL JUNI	0.0	0	1
RHY RUGO	0.0	0	1	TOR FRAG	-0.010	0	1	TOR TORT	0.0	0	2

L.4 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Cetraria tilesii Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN R EL	-0.030	1	1	SIL ACAU	2.690	1	1	ANF OENS	-0.200	1	1
SEN CYMB	-0.100	1	1	BRA RICH	0.250	1	0	LES ARCF	0.010	1	0
PAR NUOI	0.010	1	0	CAR GLAC	0.700	1	0	CAR PETR	6.230	1	1
CAR RUPE	-2.570	1	1	EMP NIGR	0.010	1	0	AND PULI	0.0	1	1
ARC ALPI	0.590	1	1	RHO LAPP	-1.250	1	1	VAC ULIG	0.0	1	1
HEO MACK	0.740	1	1	PIN VULG	0.0	1	0	TOF PUSI	0.0	1	1
POL VIVI	-0.050	1	1	AND CHAM	2.200	1	0	ANE PARV	0.010	1	0
THA ALPI	-0.160	1	1	DRY INTE	5.390	1	0	PUF BIFL	0.0	1	1
PUT FRUT	0.0	1	1	SAL ALAX	0.010	1	0	SAL BARR	0.010	1	0
PAR PALU	0.080	1	1	SAX AIZO	0.010	1	0	SAX OPPO	-0.280	1	0
PEO CAPI	0.030	1	1	PEU SUDE	-0.100	1	1	CEF TILE	-7.010	1	1
LEC EPIB	0.960	1	1	SOI BISP	-0.050	1	1	THA SUBU	0.190	1	0
SOIL LIC	0.340	1	0	SAX LICH	2.120	1	1	VER MURA	0.0	1	0
MOSS SPP	-0.100	1	1	OIT FLEA	0.0	1	0	HYP BAMB	0.0	1	0
ONC VIRE	0.0	1	0	TRI CRIS	0.0	1	0	WEI CONT	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	8.190	0	1	CHR INTE	-0.010	0	1	BRA PURP	-0.010	0	1
CAR ATFU	0.010	0	1	CAR SCIR	-7.510	0	1	KOB SIMP	-0.010	0	1
SCI CAES	0.010	0	1	CAS TETR	-0.010	0	1	HEO ALPI	-0.010	0	1
OXY JORO	0.010	0	1	TUF CUCC	-0.140	0	1	SAL ARCT	-0.010	0	1
PEU LABR	0.010	0	1	ALE OCHR	6.020	0	1	ASA CHRY	-0.700	0	1
CET CUCU	6.020	0	1	CET ISLA	4.530	0	1	CET NIVA	0.250	0	1
CLA ARBU	1.100	0	1	CLA STEL	-0.010	0	1	CLA POCI	-0.010	0	1
CLA PYXI	1.360	0	1	DAC ARCT	-0.190	0	1	OCH ANOR	-1.560	0	1
PER DACI	1.160	0	1	THA VERM	1.660	0	1	COLLEMA	0.0	0	1
POL INTE	0.700	0	1	OCHRO SP	0.0	0	1	POL JUNI	0.0	0	1
RHY RUGO	0.0	0	1	TOR TORT	0.0	0	1				

L.5 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Cetraria tilesii Tundra (n=5)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-8.180	1	1	ARE HUMI	0.010	1	0	MEL APET	0.005	2	1
MIN ARCT	0.577	4	3	MIN R EL	0.167	4	3	MIN ROSS	-0.180	1	1
SIL ACAU	-2.983	3	3	STE LAET	0.0	1	1	ANT OENS	-0.390	2	2
ANT EKMA	0.100	1	1	ARN ALPI	0.050	3	1	ARF ARCT	0.010	1	0
CHR INTE	0.010	3	3	SEN CYMB	0.005	2	1	SOL MULT	0.010	1	0
BRA PURP	0.005	2	1	ORA CORY	-0.030	1	1	PAR NUOI	-0.080	2	2
CAR CAPI	0.010	1	0	CAR GLAC	-0.720	3	1	CAR MICH	0.010	1	0
CAR MISA	0.050	2	0	CAR PETR	-1.500	2	2	CAR POOO	0.010	1	0
CAR RUPE	-0.240	1	1	CAR SCIR	-3.167	4	4	ARC ALPI	0.003	3	2
ARC UVA-	0.010	1	0	RHO LAPP	-1.787	3	3	ELY INNO	0.010	2	0
FES BRAC	0.010	1	0	POA GLAU	0.010	1	0	TRS SPIC	0.010	1	0
JUN BALT	0.010	1	0	JUN BIGL	0.010	1	0	JUN ALBE	0.040	1	0
HED ALPI	0.0	1	1	HED MACK	0.420	2	2	OXYTR SP	0.010	1	0
OXY JORO	0.0	1	1	OXY NIGR	0.010	1	0	LLD SERD	-0.080	1	1
TOF COCC	-0.065	2	2	TOF PUSI	-0.040	4	4	ZYG ELEG	0.0	1	1
EPI LATI	0.010	1	0	PAP KEEL	0.010	1	0	PAP RAUI	0.010	1	0
PIC GLAU	0.040	1	0	POL VIVI	0.034	5	4	AND CHAM	-0.558	5	5
PYR SECU	0.010	1	0	ANE PARV	0.010	2	0	THA ALPI	-0.255	4	4
DRY INTE	-12.440	4	4	POT BIFL	0.0	1	1	POT FRUT	0.005	2	1
POP BALS	0.010	2	0	SAL ALAX	4.908	5	0	SAL ARBU	0.530	4	0
SAL ARCT	0.354	5	3	SAL OODG	-0.195	2	1	SAL GLAU	0.010	2	0
SAL RETI	-0.093	3	1	SAX AIZO	0.025	2	0	SAX OPPO	0.652	5	5
PEO CAPI	0.007	3	1	PED LANA	-0.122	4	4	TER ALGA	0.900	1	0
CET CUCU	-6.010	1	1	CET TILE	-4.280	2	2	LEC EPIB	4.460	1	1
POL SENO	0.650	1	0	THA SUBU	-0.240	1	1	SOIL LIC	-1.707	3	3
SAX LICH	50.000	1	1	COLLEMA	13.000	1	1	POL INTE	0.500	2	1
MOSS SPP	0.090	4	4	AMBLYSTE	0.010	1	0	BRY PSEU	0.010	1	0
CAM STLL	0.0	1	0	CER PURP	0.010	1	0	OIT FLEX	0.0	2	1
HYP BAMB	0.0	2	1	TOM NITE	0.010	1	0	TOR ARCT	0.0	2	0
TOR TORT	0.0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-0.010	0	2	MIN ARCT	-0.010	0	1	SIL ACAU	-0.010	0	1
ANT OENS	-0.010	0	1	CHR INTE	-0.010	0	1	SEN ATRO	-0.010	0	1
SEN CYMB	0.140	0	1	BRA PURP	-0.010	0	1	BRA RICH	-0.010	0	1
LES ARCT	-0.010	0	1	PAR NUOI	-0.010	0	1	CAREX SP	-0.250	0	1
CAR ATFU	0.010	0	2	CAR MISA	-0.010	0	1	CAR PETR	-2.070	0	3
CAR RUPE	-2.443	0	4	CAR SCIR	-0.010	0	1	KOB SIMP	-0.010	0	1
SCI CAES	-0.010	0	1	EQU VARI	-0.190	0	1	AND PULI	-0.100	0	1
ARC ALPI	-0.320	0	2	CAS TETR	-0.967	0	4	RHO LAPP	-0.140	0	3
VAC ULIG	0.010	0	2	GEN PROP	-0.010	0	2	ELY INNO	-0.290	0	1
AST UMBE	-0.010	0	1	HED MACK	-0.380	0	2	OXY JORO	-0.130	0	1
PIN VULG	-0.130	0	3	TOF COCC	-0.010	0	1	PAP KEEL	-0.040	0	2
WOO GLAB	-0.010	0	1	THA ALPI	-0.250	0	1	DRY INTE	-10.540	0	1
POT BIFL	-0.010	0	2	POT FRUT	-0.010	0	2	SAL RETI	-0.010	0	1
PAR PALU	0.010	0	3	PED CAPI	-0.010	0	1	PED LABR	-0.010	0	1
PED SUDE	-0.097	0	3	ALE OCHR	-1.344	0	5	ASA CHRY	-0.283	0	1
CET CUMM	0.0	0	1	CET CUCU	-0.510	0	3	CET ERIC	-0.140	0	3
CET ISLA	-1.018	0	5	CET NIVA	-0.188	0	5	CET RICH	-0.040	0	1
CET TILE	-3.633	0	3	CLA ARBU	-0.555	0	2	CLA SFEL	-0.010	0	1
CLA POCI	-0.010	0	1	CLA PYXI	-1.360	0	1	CLA UNCI	-0.010	0	1
DAC ARCT	-0.165	0	2	DAC BERI	-0.090	0	1	DAC RAMU	-0.140	0	1
LEC EPIB	-2.580	0	1	OCH ANOR	-1.560	0	1	PER DACI	-1.360	0	2
SUL BISP	-0.090	0	1	THA SUBU	-1.027	0	3	THA VERM	-1.660	0	1
TON LOBU	-5.560	0	1	CRUSTOSE	-10.780	0	2	SOIL LIC	-5.000	0	1
SAX LICH	-0.540	0	1	POL INTE	-0.350	0	2	POL RUPE	0.0	0	1
OCHRO SP	0.0	0	1	MOSS SPP	-0.190	0	1	BRYUM SP	0.0	0	1
OIT FLEX	0.0	0	1	DRE REVO	0.0	0	1	HYPNUM	0.0	0	1
DRI CRYS	0.0	0	1	PUL JUNI	0.0	0	1	RHY RUGO	0.0	0	1
TOM NITE	0.0	0	1	TOR TORT	0.0	0	3				

L.6 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.) In Dryas integrifolia-Cetraria tilesii Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ARCT	0.010	1	0	ANT DENS	-0.380	1	1	ARN ALPI	0.010	1	0
SEN CYMB	-0.130	1	1	SOL MULT	0.010	1	0	CAR A ST	0.010	1	0
CAR ATFU	0.0	1	1	CAR CAPI	0.010	1	0	CAR GLAC	0.190	1	0
CAR MEMB	0.010	1	0	CAR NARD	0.010	1	0	CAR PETR	-2.110	1	1
CAR RUPE	-2.570	1	1	CAR SCIR	7.500	1	1	KOB SIMP	0.0	1	1
ARC ALPI	0.040	2	2	RHO LAPP	-1.250	1	1	VAC ULIG	0.030	1	1
ELY INNO	0.010	1	0	HED MACK	-0.740	1	1	TOF PUSI	0.0	1	1
ARM MARI	0.010	1	0	POL VIVI	-0.050	1	1	AND CHAM	-0.760	1	1
PYR ASAR	0.010	1	0	THA ALPI	-0.240	1	1	DRY SYLV	3.970	1	0
POT BIFL	0.0	1	1	POT TROT	0.740	1	1	POP BALS	0.010	1	0
SAL ALAX	29.550	1	0	SAL ARBU	0.010	1	0	SAL ARCT	0.590	1	1
SAL PLAN	0.010	1	0	PAR PALU	0.0	1	1	SAX AIZO	0.010	1	0
SAX OPPO	0.460	1	1	PED CAPI	0.0	1	1	PED LANA	0.010	1	0
CET TILE	-6.960	1	1	SOIL LIC	5.560	1	0	VER WORA	1.100	1	0
MOSS SPP	13.750	1	1								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-8.190	0	1	MIN R EL	-0.040	0	1	SIL ACAU	-2.700	0	1
CHR INTE	-0.010	0	1	BRA PURP	-0.010	0	1	SCI CAES	-0.010	0	1
AND POLI	-0.010	0	1	CAS TETR	-0.010	0	1	HED ALPI	-0.010	0	1
OXY JORO	-0.010	0	1	PIN VULG	-0.010	0	1	TOF COCC	-0.140	0	1
DRY INTE	-25.500	0	1	PED LABR	-0.010	0	1	PED SUDE	-0.140	0	1
ALE OCHR	-6.020	0	1	ASA CHRY	-0.700	0	1	CET CUCU	-6.020	0	1
CET ISLA	-4.530	0	1	CET NIVA	-0.250	0	1	CLA ARBU	-1.100	0	1
CLA STEL	-0.010	0	1	CLA POCI	-0.010	0	1	CLA PYXI	-1.360	0	1
DAC ARCT	-0.190	0	1	LEC EPIB	-1.100	0	1	OCH ANDR	-1.560	0	1
PER DACT	1.360	0	1	SOL BISP	-0.090	0	1	THA VERM	-1.660	0	1
COLLEMA	0.0	0	1	POL INTE	-0.700	0	1	OCHRO SP	0.0	0	1
POL JUNI	0.0	0	1	RHY RUGO	0.0	0	1	TOR TORT	0.0	0	1

L.7 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.) In Dryas integrifolia-Cetraria tilesii Tundra (n=3)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-8.180	2	2	SIL ACAU	-2.690	1	1	ANT DENS	-0.350	1	1
SEN CYMB	-0.130	1	1	CAR GLAC	0.600	1	0	CAR MEMB	2.130	2	0
CAR PETR	-2.110	1	1	CAR RUPE	-1.975	2	2	CAR SCIR	-7.500	3	3
CAR LOGE	1.350	2	0	ERI CALL	0.010	2	0	ARC ALPI	0.0	1	1
CAS TETR	0.0	1	1	JUN BALT	0.600	1	0	JUN ALBE	2.333	3	0
OXY JORO	0.0	2	2	PIN VULG	0.180	1	1	TOF PUSI	0.590	1	1
ARM MARI	0.813	3	0	POL VIVI	-0.140	2	2	AND CHAM	-0.780	3	3
ANE PARV	0.010	1	0	THA ALPI	-0.210	1	1	DRY INTE	-25.355	2	2
POT FROT	0.0	3	3	SAL ALAX	0.480	2	0	SAL ARBU	0.040	1	0
PAR PALU	0.0	1	1	PED LANA	0.010	1	0	PED SUDE	-0.130	1	1
CET CUCU	6.010	1	1	CET ISLA	-4.520	1	1	CET NIVA	-0.160	1	1
CET TILE	-6.860	1	1	CLA POCI	0.030	1	1	DAC ARCT	0.180	1	1
THA SUBU	0.340	1	0	SOIL LIC	0.440	1	0	SAX LICH	2.580	1	0
RIN ROSI	20.500	1	0	MOSS SPP	21.205	2	2	TOR RIGE	0.0	1	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ---

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	-8.190	0	1	MIN R EL	-0.040	0	3	SIL ACAU	-2.700	0	2
ANT DENS	-0.390	0	2	CHR INTE	0.010	0	3	SEN CYMB	0.140	0	2
BRA PURP	-0.010	0	3	CAR ATFO	-0.010	0	3	CAR PETR	2.120	0	2
CAR RUPE	-2.580	0	1	KOB SIMP	-0.010	0	3	SCI CAES	-0.010	0	3
AND POLI	-0.010	0	3	ARC ALPI	-0.010	0	2	CAS TETR	-0.010	0	2
RHO LAPP	-1.260	0	3	VAC ULIG	-0.010	0	3	HED ALPI	-0.010	0	3
HED MACK	-0.750	0	3	OXY JORO	-0.010	0	1	PIN VULG	-0.010	0	2
TOF COCC	0.140	0	3	TOF PUSI	0.010	0	2	POL VIVI	-0.190	0	1
THA ALPI	-0.250	0	2	DRY INTE	-25.500	0	1	POT BIFL	0.010	0	3
SAL ARCT	0.010	0	3	PAR PALU	-0.010	0	2	SAX OPPO	-0.290	0	3
PED CAPI	-0.040	0	3	PED LABR	-0.010	0	3	PED SUDE	0.140	0	2
ALE OCHR	6.020	0	3	ASA CHRY	-0.700	0	3	CET CUCU	-6.020	0	2
CET ISLA	-4.530	0	2	CET NIVA	0.250	0	2	CET TILE	-7.050	0	2
CLA ARBU	1.100	0	3	CLA STEL	-0.010	0	3	CLA POCI	0.010	0	2
CLA PYXI	-1.360	0	3	DAC ARCT	-0.190	0	2	LEC EPIB	1.100	0	3
OCH ANDR	-1.560	0	3	PER DACT	-1.360	0	3	SOL BISP	0.090	0	3
THA VERM	-1.660	0	3	COLLEMA	0.0	0	3	POL INTE	0.700	0	3
OCHRO SP	0.0	0	3	MOSS SPP	0.800	0	1	POL JUNI	0.0	0	3
RHY RUGO	0.0	0	3	TOR TORT	0.0	0	3				

M.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.) In Dryas integrifolia-Rhizocarpon umbilicatum Tundra (n=5)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF	DISTB	CONTR
OTHR VAS	0.040	1	0	MEL APET	0.047	4	1	MIN ARCT	-0.698	5	5
MIN R EL	0.855	4	1	MIN ROSS	0.150	1	1	SIL ACAU	0.005	2	1
STE EDWA	0.010	1	0	STE MONA	0.047	3	0	ARN ALPI	0.0	1	1
CHR INTE	0.0	1	1	SEN CYMB	-0.120	3	2	BRA PURP	0.006	5	3
DRA CORY	0.062	5	4	PAR NUDI	0.006	5	5	CAR GLAC	0.010	1	0
CAR MEMB	0.0	1	1	CAR MISA	-1.650	1	1	CAR SCIR	-2.110	1	1
ERI ANGU	0.0	1	1	EQU SCIR	0.010	1	0	EQU VARI	-0.080	1	1
POA SP	0.010	4	0	TRS SPIC	0.050	2	0	JUN BIGL	0.0	1	1
OXY JORO	0.010	1	0	TOF PUSI	0.0	1	1	PAP KEEL	0.064	5	1
ARM MARI	0.005	2	1	POL VIVI	-0.065	2	2	AND CHAM	-0.115	2	1
DRY DRUM	0.010	1	0	DRY INTE	-9.422	5	5	POT BIFL	0.010	1	0
SAL ALAX	2.962	5	0	SAL ARBU	0.010	2	0	SAL ARCT	-0.080	2	1
SAL DODG	-0.054	5	4	SAL PULA	0.0	2	2	SAL A XP	0.010	1	0
SAL RETI	-1.037	3	2	SAX AIZO	0.440	1	0	SAX OPPO	-0.175	4	4
PED CAPI	-0.130	1	1	PED LANA	-0.015	2	2	PED SUDE	-0.590	1	1
SOIL LIC	0.140	1	0	MOSS SPP	-0.060	1	1				

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MEL APET	-0.010	0	1	MIN ROSS	-0.190	0	2	SIL ACAU	-0.010	0	3
STELL SP	-0.190	0	3	ANT DENS	-0.010	0	3	CHR INTE	-0.332	0	4
SAU ANGU	-0.010	0	1	SEN ATRO	-1.510	0	1	SEN CYMB	-0.140	0	2
EUT EDWA	-0.010	0	1	SME BORE	-0.010	0	1	CAR ATFU	-1.100	0	1
CAR GLAC	-0.340	0	1	CAR MEMB	-0.010	0	3	CAR MISA	-0.340	0	3
CAR PETR	-0.010	0	1	CAR RUPE	-0.677	0	4	CAR VAGI	-0.010	0	1
ERI ANGU	-0.010	0	3	ERI SCHE	-0.090	0	1	KOB MYOS	-1.660	0	1
KOB SIMP	-0.010	0	1	ARC ALPI	-0.010	0	1	CAS TETR	-0.010	0	4
VAC ULIG	-8.540	0	1	JUN BIGL	-0.070	0	3	LOZ NIVA	-0.010	0	1
AST UMBE	-0.340	0	1	LLO SERO	-0.025	0	2	PAP RADI	-0.140	0	3
POL BIST	-0.140	0	1	POL VIVI	-0.613	0	3	AND CHAM	-0.010	0	3
THA ALPI	-0.325	0	2	POT BIFL	-0.010	0	1	POT UNIF	-0.010	0	1
SAL ARCT	-0.290	0	3	SAL POLA	-0.010	0	1	SAX OPPO	-0.010	0	1
PED LANA	-0.010	0	3	PED ARCT	-0.010	0	1	TER ALGA	-0.540	0	1
ALE OCHR	-0.010	0	1	CET CUCU	-1.550	0	2	CET ISLA	-0.090	0	1
CET NIVA	0.190	0	1	CET PINA	-0.010	0	1	CET TILE	-0.066	0	5
CLA PHYL	-0.010	0	1	CLA POCI	-0.010	0	1	DAC ARCT	-0.010	0	1
DAC BERI	0.010	0	4	EVE PERF	-0.010	0	1	LEC EPIB	-0.090	0	1
THA SUBU	-0.386	0	5	SOIL LIC	-3.227	0	4	RHI UMBI	-12.450	0	3
HEPATICS	-0.003	0	4	MOSS SPP	-3.813	0	4	CAM STEL	0.0	0	1
DIT FLEX	0.0	0	1	HYL SPLE	-0.010	0	1	HYP BAMB	0.0	0	5
TOM NITE	0.0	0	1	TOR ARCT	0.0	0	3	TOR TORT	0.0	0	4

H.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Rhizocarpon umbilicatum Tundra (n=5)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MEL APET	0.102	4	2	MIN ARCT	-0.642	4	4	MIN R EL	0.320	4	1
MIN ROSS	0.250	1	1	SIL ACAU	0.003	3	2	STE EDWA	0.010	1	0
STE LAET	0.010	2	0	STE MONA	0.040	1	0	ANTEN SP	0.040	1	0
ARN ALPI	0.0	1	1	SEN CYMB	-0.023	3	2	BRA PURP	0.117	3	1
DRA CORY	0.122	4	3	PAR NUDI	0.060	3	3	SME BURE	0.0	1	1
CAR A ST	0.500	1	0	CAR ATFU	0.065	2	2	CAR GLAC	-0.330	1	1
CAR MEMB	1.867	3	2	CAR MICG	0.010	1	0	CAR MISA	-0.455	4	3
CAR PETR	0.010	1	0	CAR SCIR	-1.070	4	2	CAR VAGI	2.790	1	1
ERI ANGU	-0.947	4	3	ERI SCHE	0.290	1	0	ERI VAGI	0.010	1	0
KOB MYOS	-0.730	2	1	KOB SIMP	0.493	3	2	EQU VARI	-0.080	1	1
RHO LAPP	0.0	1	1	GEN PROP	0.010	1	0	FES RUBR	0.010	1	0
POA SP	0.010	2	0	POA GLAU	0.010	1	0	IRS SPIC	0.010	1	0
JUN BALT	0.010	1	0	JUN BIGL	-0.090	2	2	JUN CAST	0.010	1	0
JUN ALBE	1.420	3	1	TRI PALU	0.010	1	0	PIN VULG	0.0	1	1
LLO SERO	-0.007	3	2	TOF PUST	-0.255	2	2	PAP KEEL	0.010	1	0
PAP RADI	0.215	2	2	ARM MARI	0.0	1	1	POL VIVI	-0.440	5	5
AND CHAM	0.027	4	3	ANE PARV	0.010	2	0	THA ALPI	0.630	1	1
DRY INTE	-11.214	5	5	POT FRUT	0.010	1	0	SAL ALAX	1.413	3	0
SAL ARBU	0.010	1	0	SAL ARCT	-0.857	3	3	SAL DODG	0.140	4	3
SAL POLA	0.123	3	2	SAL RETI	-2.935	4	3	SAX AIZO	0.010	1	0
SAX OPPO	0.140	5	4	PED LANA	-3.460	2	2	PED SUDE	-0.290	2	1
TER ALGA	-0.160	1	1	CET CUCU	-0.590	1	1	CET NIVA	0.0	1	1
CET TILE	-0.675	2	2	CLADO SP	0.010	1	0	LEC EPIB	-5.040	1	1
SOL BISP	-0.475	2	1	THA SUBU	-0.030	1	1	CRUSTOSE	0.340	1	0
SOIL LIC	4.597	3	2	POL GELA	0.0	1	0	MOSS SPP	-1.740	2	2
BRYUM SP	0.0	1	0	BRY PSEU	0.0	1	0	CAM S AR	0.0	1	0
CAT NIGR	0.0	1	0	DRE REVO	0.0	1	0	HYP BAMB	0.0	1	1
RHI PUNC	0.0	1	0	RHY RUGO	0.0	1	0	TOM NITE	0.0	1	1
TOR FRAG	0.0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN R EL	-0.250	0	1	MIN ROSS	-0.190	0	1	SIL ACAU	-0.010	0	1
STELL SP	-0.190	0	2	ANT DENS	-0.010	0	2	CHR INTE	-0.225	0	4
SAU ANGU	-0.010	0	1	SEN ATRO	-1.510	0	1	SEN CYMB	-0.250	0	1
BRA PURP	-0.140	0	1	EUT EDWA	-0.010	0	1	PAR NUDI	0.010	0	1
CAR CAPI	-0.340	0	1	CAR MEMB	-0.010	0	2	CAR MISA	-0.190	0	1
CAR PETR	0.010	0	1	CAR RUPE	-0.603	0	3	CAR VAGI	-0.010	0	1
ERI ANGU	-0.010	0	1	ERI CALL	-0.800	0	1	ERI SCHE	-0.090	0	1
ARC ALPI	-0.010	0	2	CAS TETR	-0.010	0	4	VAC ULIG	-8.540	0	1
ARC LATI	-0.040	0	1	JUN BIGL	-0.010	0	1	LUZ NIVA	-0.010	0	1
AST UMBE	0.340	0	1	PAP KEEL	-0.040	0	1	POL BIST	-0.140	0	1
AND CHAM	-0.010	0	1	PYROL SP	-0.010	0	1	THA ALPI	-0.010	0	2
POT BIFL	-0.010	0	1	PUT UNIF	-0.010	0	1	SAL ARCT	-0.290	0	1
SAX HIRC	-0.010	0	1	PED CAPI	-0.075	0	2	PED LANA	0.010	0	3
PED ARCT	-0.010	0	2	TER ALGA	-0.540	0	1	ALE OCHR	0.025	0	2
CET CUCU	-1.550	0	2	CET ISLA	-0.090	0	1	CET LAEV	-0.010	0	1
CET NIVA	-0.190	0	1	CET PINA	-0.010	0	1	CET TILE	-0.103	0	3
CLA PHYL	-0.010	0	1	CLA POCI	0.010	0	1	DAC ARCT	-0.010	0	2
DAC BERI	-0.010	0	3	DAC RAMU	-0.010	0	1	EVE PERF	-0.010	0	1
LEC EPIB	-0.090	0	1	POL SEND	2.580	0	1	THA SUBU	-0.480	0	4
SOIL LIC	-0.700	0	1	RHI UMBI	-12.450	0	2	HEPATICS	-0.003	0	3
MOSS SPP	-5.000	0	3	BRY TORT	0.0	0	1	CAM STEL	0.0	0	1
DIS CAPI	0.0	0	1	DIS INCL	0.0	0	1	DIT FLEX	0.0	0	2
HYL SPLE	-0.010	0	1	HYPNUM	0.0	0	1	HYP BAMB	0.0	0	4
MYU JULA	0.0	0	1	URT CRYS	0.0	0	1	TOM NITE	0.0	0	1
TOR ARCT	0.0	0	2	TOR FRAG	0.0	0	1	TUR TORT	0.0	0	1

H.3 Cover Differences (Cov.Dif.) Between Bulldozer Tracks (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Rhizocarpon umbilicatum Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB.	CONTR	SPECIES	COV DIF.	DISTB	CONTR
MEL APET	0.0	1	1	MIN ARCT	-1.520	1	1	MIN R EL	0.190	1	0
ANT EKMA	0.010	1	0	ARN ALPI	0.0	1	1	SEN ATRO	-1.500	1	1
SEN CYMB	0.040	1	0	BRA PURP	0.010	1	0	CAR ATFU	-1.090	1	1
CAR MEMB	0.380	1	1	CAR MISA	0.460	1	1	CAR PETR	0.010	1	0
CAR SCIR	0.0	1	1	ERI ANGU	0.180	1	1	KOB SIMP	1.550	1	1
EQU VARI	-0.080	1	1	IRS SPIC	0.010	1	0	JUN BIGL	-0.050	1	1
AST UMBE	-0.330	1	1	LLO SERO	0.030	1	1	PAP KEEL	0.100	1	1
POT BIST	0.050	1	1	POL VIVI	-1.270	1	1	AND CHAM	0.010	1	0
ANE PARV	0.140	1	0	THA ALPI	0.060	1	1	DRY INTE	-9.540	1	1
POT BIFL	0.0	1	1	SAL ALAX	0.750	1	0	SAL ARBU	0.010	1	0
SAL ARCT	3.390	1	1	SAL DODG	0.140	1	0	SAL RETI	-2.810	1	1
PED SUDE	-0.590	1	1	SOL BISP	0.010	1	0	SOIL LIC	1.880	1	1
SAX LICH	1.560	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF.	DISTB.	CONTR.	SPECIES	COV DIF	DISTB.	CONTR
SIL ACAU	0.010	0	1	CHR INTE	-0.010	0	1	SAU ANGU	-0.010	0	1
EUT EDWA	-0.010	0	1	PAR NUDI	-0.010	0	1	CAR VAGI	-0.010	0	1
ERI SCHE	0.090	0	1	KOB MYOS	-1.660	0	1	ARC ALPI	-0.010	0	1
VAC ULIG	-8.540	0	1	LUZ NIVA	-0.010	0	1	TOF PUST	-0.010	0	1
ARM MARI	-0.010	0	1	SAX OPPO	-0.010	0	1	PED CAPI	-0.140	0	1
PED LANA	0.010	0	1	PED ARCT	-0.010	0	1	TER ALGA	-0.540	0	1
CET CUCU	-2.850	0	1	CET TILE	-0.010	0	1	CLA PHYL	-0.010	0	1
CLA POCI	-0.010	0	1	DAC ARCT	-0.010	0	1	THA SUBU	-0.950	0	1
HEPATICS	-0.010	0	1	MOSS SPP	-14.500	0	1	CAM STEL	0.0	0	1
DIT FLEX	0.0	0	1	HYL SPLE	-0.010	0	1	HYP BAMB	0.0	0	1
TOM NITE	0.0	0	1								

H.4 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Rhizocarpon umbilicatum Tundra (n=4)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
CAM UNIF	0 010	1	0	MEL APET	0 005	2	1	MIN ARCT	0 160	4	3
MIN R EL	0 310	2	1	MIN ROSS	-0 180	1	1	SIL ACAU	0 0	1	1
STE EDWA	0 010	1	0	STE MONA	0 010	1	0	CHR INTE	0 020	2	1
SENEC SP	0 010	1	0	SEN CYMB	-0 240	1	1	BRA PURP	-0 130	1	1
DRA CORY	-0 020	3	3	LES ARCT	0 010	1	0	PAR NUDI	0 320	2	2
SME ORHE	0 280	1	1	CAR ATFU	-0 180	1	1	CAR GLAC	-0 330	1	1
CAR MEMB	-1 270	3	2	CAR MICG	0 250	1	0	CAR MISA	1 055	2	1
CAR SCIR	-1 280	2	1	ERI ANGU	-5 450	1	1	KOB MYOS	0 010	1	0
KOB SIMP	5 930	1	1	ARC ALPI	0 005	2	1	POA SP	0 010	2	0
POA ARCT	0 010	1	0	TRS SPIC	0 010	1	0	JUN BALT	0 010	1	0
JUN BIGL	0 0	1	1	JUN ALBE	-0 250	1	1	HED MACK	0 010	1	0
OXY JORO	0 010	1	0	OXY NIGR	0 010	1	0	PIN VULG	0 130	1	1
LLO SERO	0 005	2	1	TOF COCC	0 010	1	0	TOF PUSI	-0 610	1	1
PAPAV SP	0 010	2	0	PAP KEEL	0 010	2	0	ARM MART	0 010	1	0
POL VIVI	-0 190	4	4	CLA MEGA	0 010	1	0	ANO CHAM	0 705	2	2
THA ALPI	0 070	2	1	DRY DRUM	0 010	1	0	DRY INTE	-14 235	2	2
POT FRUT	0 010	1	0	POT VAHL	0 330	2	0	SAL ALAX	0 453	3	0
SAL ARBU	0 010	1	0	SAL ARCT	0 170	2	1	SAL OODG	-0 220	3	3
SAL GLAU	0 010	1	0	SAL POLA	0 0	2	2	SAL A XP	0 010	1	0
SAL RETI	4 495	2	2	PAR PALD	0 010	1	0	SAX AIZO	0 040	1	0
SAX OPPO	0 157	3	2	PED LANA	-3 000	2	2	PED SUDE	0 010	1	0
ALE OCHR	-0 030	1	1	CET TILE	-0 800	2	2	THA SUBU	-0 030	1	1
SOIL LIC	14 500	1	0	MOSS SPP	-3 020	2	2	BRYUM SP	0.0	1	0
ENC ALPI	0 010	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN R EL	0 250	0	1	MIN ROSS	-0 190	0	1	SIL ACAO	-0 010	0	1
STELL SP	-0 190	0	2	ANT DENS	0 010	0	2	CHR INTE	0 440	0	2
SEN CYMB	0 140	0	2	BRA PURP	-0 140	0	1	PAR NUDI	-0 010	0	1
CAR CAPI	0 340	0	1	CAR MEMB	-0 010	0	2	CAR MISA	-0 340	0	2
CAR PLIR	-0 010	0	1	CAR RUPE	-0 603	0	3	CAR VAGI	-0 250	0	1
ERI ANGU	-0 010	0	2	ERI CALL	-0 800	0	1	CAS TETR	-0 010	0	4
RHO LAPP	0 010	0	1	ARC LATI	-0 040	0	1	JON DIGL	-0 010	0	1
PAP RADI	0 140	0	2	ANO CHAM	-0 010	0	2	PYROL SP	-0 010	0	1
THA ALPI	0 010	0	1	DRY INTE	-6 900	0	2	POT UNIF	-0 010	0	1
SAL ARCT	0 290	0	2	SAX HIRC	-0 010	0	1	SAX OPPO	-0 540	0	1
PED CAPI	0 010	0	1	PED LANA	-0 025	0	2	PED ARCT	-0 010	0	1
TER ALGA	0 250	0	1	ALE OCHR	-0 010	0	1	CET COCU	0 425	0	2
CET ISLA	-0 090	0	1	CET LALV	-0 010	0	1	CET NIVA	-0 100	0	2
CET PINA	0 010	0	1	CET TILE	-0 010	0	2	DAC ARCT	-0 010	0	1
DAC BERI	-0 010	0	3	DAC RAMU	0 010	0	1	EVE PERF	0 010	0	1
LEC EPIB	-2 570	0	2	POL SENO	-2 580	0	1	SOL BISP	1 000	0	1
THA SUBU	0 323	0	3	SOIL LIC	-4 070	0	2	RHI OMBT	-12 450	0	2
HEPATICS	0 0	0	2	MOSS SPP	-0 250	0	2	BRY TORT	0 0	0	1
DIS CAPI	0 0	0	1	DIS INCL	0 0	0	1	DIT FLEX	0 0	0	1
HYPNUM	0 0	0	1	HYP BAMB	0 0	0	4	MYU JULA	0 0	0	1
ORT CRYS	0 0	0	1	TOM NITE	0 0	0	1	TOR ARCT	0 0	0	2
TOR FRAG	0 0	0	1	TOR TORT	0 0	0	3				

H.5 Cover Differences (Cov.Dif.) Between Pit Access Roads (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Rhizocarpon umbilicatum Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN ARCT	0 0	1	1	MIN R EL	0 150	1	1	ANT DENS	0 010	1	0
SEN CYMB	-0 210	1	1	BRA PURP	0.040	1	0	DRA CORY	1 550	1	1
PAR NUDI	0 0	1	1	SME BORE	0 030	1	1	CAR GLAC	0 0	1	1
CAR MISA	1 210	1	0	TRS SPIC	0.010	1	0	LLO SERO	-0 030	1	1
PAP KEEL	0 010	1	0	POL VIVI	0 630	1	1	ANO CHAM	-0 210	1	1
DRY INTE	-12 010	1	1	POT UNIF	0 590	1	1	SAL ALAX	4 190	1	0
SAL ARCT	0 390	1	0	SAL DODG	-0 050	1	1	SAL POLA	0 010	1	0
SAL RETI	0 030	1	1	SAX OPPO	-0.030	1	1	PEO LANA	-0.030	1	1
CET TILE	-0 280	1	1								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MEL APET	-0 010	0	1	CHR INTE	-0 010	0	1	CAR PETR	-0 010	0	1
CAR RUPE	-0 010	0	1	CAS TETR	-0 010	0	1	THA ALPI	-0 010	0	1
ALE OCHR	-0 010	0	1	CET COCO	-0 250	0	1	CET ISLA	-0.090	0	1
CET NIVA	-0 190	0	1	CET PINA	-0 010	0	1	DAC BERI	-0 010	0	1
EVE PERF	-0 010	0	1	LEC EPIB	-0 090	0	1	THA SUBU	-0.950	0	1
MOSS SPP	-0 250	0	1	HYP BAMB	0 0	0	1	TOR TORT	0.0	0	1

H.6 Cover Differences (Cov.Dif.) Between Oil Spills (Distb.) and Their Controls (Contr.)

In Dryas integrifolia-Rhizocarpon umbilicatum Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
DRA CORY	0 0	1	1	PAR NUDI	0 0	2	2	CAR MEMB	0 010	1	0
CAR MISA	0 040	1	0	CAR SCIR	0 010	1	0	ERI ANGU	0 010	1	0
CAS TETR	0 0	2	2	TRS SPIC	0 010	2	0	POL VIVI	0 0	1	1
ANE PARV	0 010	1	0	DRY INTE	-12 390	1	1	SAL ARCT	0 010	2	0

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MEL APET	0 010	0	2	MIN ARCT	-0 010	0	2	MIN R EL	-0 040	0	2
CHR INTE	-0 010	0	2	SEN CYMB	-0 250	0	2	DRA CORY	-0 010	0	1
SMI BORE	-0 010	0	2	CAR GLAC	-0 340	0	2	CAR PETR	-0 010	0	2
CAR RUPE	-0 010	0	2	ELO SERO	-0.040	0	2	POL VIVI	-0 010	0	1
ANO CHAM	-0 250	0	2	THA ALPI	-0 010	0	2	DRY INTE	-12 400	0	1
POT UNIF	-0 010	0	2	SAL DODG	0 190	0	2	SAL RETI	-0 010	0	2
SAX OPPO	-0 040	0	2	PEO LANA	-0 040	0	2	ALE OCHR	-0 010	0	2
CET COCU	-0 250	0	2	CET ISLA	-0 090	0	2	CET NIVA	-0.190	0	2
CET PINA	-0 010	0	2	CET TILE	-0 290	0	2	DAC BERI	-0 010	0	2
EVE PERF	-0 010	0	2	LEC EPIB	-0 090	0	2	THA SUBO	-0 950	0	2
HEPATICS	0 0	0	2	MOSS SPP	-0 250	0	2	CAM STEL	0.0	0	2
HYP BAMB	0 0	0	2	TOR TORT	0 0	0	2				

N.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Saxicolous Lichen-Lecanora epibyron Tundra (n=3)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ARE HUMI	0.010	1	0	MEL APET	-0.023	3	2	MIN ARCT	0.037	3	3
MIN R EL	0.0	1	1	MIN ROSS	1.480	2	1	STE EDWA	0.140	1	0
ANT DENS	0.010	1	0	CHR INTE	-0.050	1	1	SEN CYMB	0.0	2	2
BRA PURP	0.333	3	2	DRA CORY	0.013	3	3	LES ARCT	0.010	1	0
PAR NUDI	-0.197	3	3	GRAMINEA	0.700	1	0	POA SP	0.010	1	0
POA GLAU	0.010	2	0	TRS SPIC	0.010	1	0	PAP KEEL	-0.130	1	1
POL VIVI	-0.065	2	2	AND CHAM	-0.130	1	1	THA ALPI	0.600	1	0
DRY INTE	-4.273	3	3	DRY OCTO	0.010	1	0	PUT BIFL	0.010	1	0
SAL ALAX	2.125	2	1	SAL ARCT	0.685	2	2	SAL DOOG	-0.610	3	3
SAL POLA	0.0	1	1	SAX OPPO	-0.610	3	3	ALE OCHR	0.040	1	0
SOIL LIC	-32.440	1	1	MOSS SPP	-0.050	1	1	BRYUM SP	0.0	1	0
CAM STEL	0.0	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MIN R EL	-0.900	0	1	CHR INTE	0.010	0	2	SEN ATRO	-0.090	0	1
SEN CYMB	-0.010	0	1	CAR ATFU	-0.010	0	1	CAR GLAC	-0.250	0	1
CAR MISA	-1.180	0	2	CAR PETR	-4.850	0	1	CAR RUPE	-1.800	0	2
CAR SCIR	-2.555	0	2	ERI ANGU	-0.010	0	1	KOB SIMP	-0.010	0	1
CAS TETR	0.010	0	1	LLO SERO	0.010	0	2	TOF PUSI	-0.190	0	1
PAP KEEL	-0.025	0	2	POL VIVI	-0.010	0	1	WOO GLAB	-0.010	0	1
AND CHAM	-0.025	0	2	THA ALPI	-0.250	0	1	POT VAHL	-0.040	0	1
SAL ARBU	0.010	0	1	SAL ARCT	-0.140	0	1	SAL POLA	-0.010	0	1
SAL RETI	0.010	0	1	PEDIC SP	0.010	0	1	PED LANA	0.265	0	2
PED ARCT	-0.010	0	1	ALE OCHR	-0.010	0	1	CET ISLA	-0.010	0	1
CET NIVA	0.010	0	1	CET TILE	-0.737	0	3	DAC RAMU	-0.010	0	1
LEC EPIB	23.500	0	1	SOL BISP	-0.140	0	1	THA SUBU	0.037	0	3
SOIL LIC	-13.010	0	1	SAX LICH	-29.967	0	3	POL HYPE	0.0	0	1
POL GOTH	0.0	0	1	POL INTE	0.0	0	2	MOSS SPP	-0.145	0	2
AMBLYSTE	0.0	0	1	BRA TURG	0.0	0	1	BRYUM SP	0.0	0	1
CAT NIGR	0.0	0	1	DIT FLEX	0.0	0	1	HYP BAMB	-0.003	0	3
DRI CRYS	0.0	0	1	TOM NITE	0.0	0	1	TOR ARCT	0.0	0	1
TOR TORT	0.0	0	1								

N.2 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In Saxicolous Lichen-Lecanora epibyron Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MEL APET	-0.080	1	1	MIN ARCT	0.0	1	1	MIN R EL	-0.250	1	1
CHR INTE	-0.050	1	1	SEN CYMB	0.0	1	1	DRA CORY	-0.250	1	1
CAR GLAC	-0.240	1	1	CAR PETR	-4.840	1	1	CAR RUPE	-2.840	1	1
AND CHAM	-0.130	1	1	THA ALPI	-0.240	1	1	DRY INTE	0.0	1	1
SAL ALAX	0.130	1	1	SAL ARCT	-0.030	1	1	SAL DOOG	-0.080	1	1
SAX OPPO	0.210	1	1	DAC RAMU	0.010	1	0	SAX LICH	-14.260	1	1

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BRA PURP	-0.010	0	1	PAR NUDI	-0.010	0	1	CAR ATFU	-0.010	0	1
CAR SCIR	-5.100	0	1	KOB SIMP	-0.010	0	1	CAS TETR	-0.010	0	1
LLO SERO	0.010	0	1	TOF PUSI	-0.190	0	1	PAP KEEL	-0.010	0	1
POL VIVI	-0.140	0	1	WOO GLAB	-0.010	0	1	POT VAHL	-0.040	0	1
SAL POLA	0.010	0	1	SAL RETI	-0.010	0	1	PEDIC SP	-0.010	0	1
PED LANA	-0.390	0	1	CET TILE	-0.010	0	1	LEC EPIB	-23.500	0	1
THA SUBU	-0.010	0	1	POL HYPE	0.0	0	1	MOSS SPP	-0.010	0	1
AMBLYSTE	0.0	0	1	BRYUM SP	0.0	0	1	CAT NIGR	0.0	0	1
HYP BAMB	-0.010	0	1	TOM NITE	0.0	0	1	TOR ARCT	0.0	0	1

N.3 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In Saxicolous Lichen-Lecanora epibyron Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
MEL APET	-0.050	1	1	MIN ARCT	-0.215	2	2	MIN R EL	-0.250	1	1
MIN ROSS	0.005	2	1	STE EDWA	0.010	1	0	STE MUNA	0.010	1	0
AST ALPI	0.010	1	0	BRA PURP	0.0	1	1	DRA CORY	-0.150	2	2
PAR NUDI	-0.590	1	1	CAR GLAC	-0.060	1	1	CAR MISA	0.650	1	0
POA SP	0.010	1	0	TRS SPIC	0.140	1	0	LLO SERO	0.030	1	1
PAP KEEL	0.030	1	1	POL VIVI	0.125	2	2	AND CHAM	0.010	2	2
DRY INTE	-2.635	2	2	SAL ALAX	0.070	2	1	SAL ARBU	0.0	1	1
SAL ARCT	-0.030	1	1	SAL DOOG	-0.190	2	2	SAL GLAU	0.010	1	0
SAL POLA	0.0	1	1	SAL A XP	0.010	1	0	SAL RETI	0.010	1	0
SAX OPPO	0.315	2	2	PED LANA	-0.380	1	1	PED SUDE	0.010	1	0
SOIL LIC	43.500	1	0	COLLEMA	0.0	1	0	HYP BAMB	0.010	1	1

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
CHR INTE	-0.050	0	2	SEN CYMB	-0.010	0	2	PAR NUDI	-0.010	0	1
CAR ATFU	-0.010	0	1	CAR MISA	-0.800	0	1	CAR PETR	-4.850	0	1
CAR RUPE	-2.850	0	1	CAR SCIR	-5.100	0	1	KOB SIMP	-0.010	0	1
CAS TETR	-0.010	0	1	TOF PUSI	-0.190	0	1	PAP KEEL	-0.010	0	1
WOO GLAB	0.010	0	1	THA ALPI	-0.250	0	1	POT VAHL	-0.040	0	1
SAL ARCT	-0.140	0	1	SAL POLA	-0.010	0	1	SAL RETI	-0.010	0	1
PEDIC SP	-0.010	0	1	CET TILE	-1.100	0	2	LEC EPIB	-23.500	0	1
SOL BISP	-0.140	0	1	THA SUBU	-0.050	0	2	SOIL LIC	-13.010	0	1
SAX LICH	-30.200	0	2	POL HYPE	0.0	0	1	POL GOTH	0.0	0	1
POL INTE	0.0	0	1	MOSS SPP	-0.145	0	2	AMBLYSTE	0.0	0	1
BRA TURG	0.0	0	1	BRYUM SP	0.0	0	1	CAT NIGR	0.0	0	1
HYP BAMB	-0.010	0	1	DRI CRYS	0.0	0	1	TOM NITE	0.0	0	1
TOR ARCT	0.0	0	1	TOR TORT	0.0	0	1				

D.1 Cover Differences (Cov.Dif.) Between Roads (Distb.) and Their Controls (Contr.)

In Rhizocarpon inarense-Umbilicaria proboscidea Tundra (n=4)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0 010	1	0	ARE HUMI	0 010	1	0	MIN ARCT	0 010	1	0
MIN BIFL	0 010	1	0	MIN MACR	0 225	2	0	MIN R EL	0 090	3	0
MIN RUBE	5 560	2	0	SIL ACAU	0 070	3	0	STELL SP	0 040	1	0
ANTEN SP	0 010	1	0	ANT DENS	0 010	1	0	ANT MONO	0 010	1	0
ARN LESS	0 010	1	0	ART ARCT	0 010	3	0	ERI HUMI	0 010	1	0
PET FRIG	0 010	1	0	SOL MULT	0 010	2	0	CAR BELL	0 010	2	0
CAREX SP	0 010	1	0	CAR GLAC	0 010	1	0	CAR MICH	1 600	3	0
CAR NARD	0 010	1	0	CAR PETR	2 090	1	0	EMP NIGR	0 010	1	0
CAS TETR	0 010	1	0	LEO DECU	0 010	1	0	VAC ULIG	0 010	1	0
AGP VIOL	0 010	1	0	CAL PURP	0 010	1	0	FES ALTA	0 010	1	0
FES BRAC	0 063	3	0	POA SP	0 010	1	0	POA ALPG	0 010	1	0
POA ARCT	0 075	2	0	TRS SPIC	1 063	3	0	JUN CAST	0 010	2	0
JON ALBE	0 010	1	0	LOZ CONF	0 283	3	0	OXY NIGR	0 010	1	0
EPI LATI	0 010	2	0	POL VIVI	0 010	3	0	AND CHAM	0 010	2	0
ANE PARV	0 010	2	0	DRY INTE	0 010	2	0	DRY OCTO	0 010	1	0
POT BIFL	0 010	1	0	POT ELEG	0 010	1	0	POT FROT	0 010	2	0
POT HYPA	0 010	1	0	POT ONIF	1 050	2	0	POP BALS	0 010	1	0
SAL ALAX	0 010	4	0	SAL ARBU	0 010	2	0	SAL PLAN	0 010	1	0
SAL POLA	0 010	1	0	SAL RETI	0 010	2	0	SAX OPPO	0 010	1	0
SAX TRIC	0 010	1	0	CET CUCO	0 010	1	0	PEL CANI	0 010	1	0
STE TOME	0 010	3	0	UMB PROB	-35 460	1	1	SOIL LIC	1 310	1	0
COLLEMA	0 010	1	0	RHI UMBI	0.250	1	0	STERE SP	0 0	1	0
HEPATICS	0 010	1	0	MOSS SPP	3 415	2	2	POLYT SP	2 390	1	0
ABI ABIE	0 010	1	0	CER PURP	0 0	1	0	POG ALPI	0 0	1	0
POL JUNI	1 200	1	0	TOR TORT	0 0	1	0	TOR RORA	0 010	1	0
TOR MUCR	0 010	1	0	ORTHOTRI	0 0	1	1				

-------- IN CONTROLS BUT NOT IN DISTURBANCES ---

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
AGY RIGI	0 290	0	1	ALE OCHR	-0 010	0	1	BAC ALPI	-0 010	0	1
CET TILE	0 010	0	1	CLA COCC	-0 010	0	1	CLA DEFO	-0 010	0	1
CLA G GR	-0 010	0	1	CLA PLEO	-0 097	0	3	DAC ARCT	-0 010	0	1
DAC RAMU	0 010	0	2	OMP DECU	0 440	0	1	OMP KRAS	0 440	0	1
PAR CENT	0 010	0	2	PHY CAES	-0 010	0	1	POL SENO	0 0	0	1
UMB HYPE	-3 040	0	2	UMB PROB	-35 500	0	1	CRUSTOSE	-18 227	0	3
SAX LICH	-31 000	0	1	RHIZO SP	-32 260	0	2	RHI INAR	-9 050	0	2
LEC PANT	0 0	0	2	LEC GLAU	0 0	0	1	LECIDEA	-0 010	0	1
HEPATICS	0 0	0	1	MOSS SPP	-0 900	0	2	AND RUPE	0 0	0	3
GRIMMIA	0 0	0	1	RHA LANU	-0 005	0	4				

D.2 Cover Differences (Cov.Dif.) Between False Start Roads (Distb.) and Their Controls (Contr.)

In Rhizocarpon inarense-Umbilicaria proboscidea Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV.DIF	DISTB	CONTR.	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0 040	1	0	MIN R EL	0 010	1	0	SIL ACAU	0.010	1	0
STE LAET	0 250	1	0	ANT MONO	0 010	1	0	ART ARCT	0 010	1	0
ERI HUMI	0 010	1	0	SOL MULT	0 010	1	0	CAR BELL	0.010	1	0
DRA GLAB	0 440	1	0	CAR PETR	0 010	1	0	CAR LUGE	4.070	1	0
EMP NIGR	0 010	1	0	EDO SCIR	0 010	1	0	CAL PURP	0 010	1	0
FES ALTA	0 010	1	0	POA ALPN	0 010	1	0	POA ARCT	0 650	1	0
TRS SPIC	0 010	1	0	PIC GLAU	0 010	1	0	OXY DIGY	0 010	1	0
POL VIVI	0 140	1	0	CYS FRAG	0 010	1	0	ANE PARV	0 010	1	0
THA ALPI	0 010	1	0	DRY INTE	0 010	1	0	POT FRUT	0 010	1	0
POP BALS	0 190	1	0	SAL ALAX	0 040	1	0	SAL ARBU	2.250	1	0
SAL DOUG	0 010	1	0	PEL RUFE	0 010	1	0	MOSS SPP	-1.830	1	1
ABI ABIE	0 010	1	0	CAM CHRY	0 0	1	0	CER PURP	0.010	1	0
HYP REVO	0 010	1	0	TOR FRAG	0 0	1	0	TOR TORT	0.010	1	0
TOR MOCR	0 010	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ALE OCHR	0 010	0	1	BAC ALPI	-0.010	0	1	CLA COCC	-0 010	0	1
CLA DEFO	-0 010	0	1	CLA G GR	-0 010	0	1	CLA PLEU	-0 010	0	1
DAC RAMU	-0 010	0	1	OMP DECU	-0 440	0	1	OMP KRAS	-0 440	0	1
PAR CENT	-0 010	0	1	PHY CAES	-0 010	0	1	POL SENO	0 0	0	1
CRUSTOSE	-37 500	0	1	RHIZO SP	-53 000	0	1	LECIDEA	-0 010	0	1
HEPATICS	0 0	0	1	AND ROPE	0.0	0	1	RHA LANU	-0 010	0	1

D.3 Cover Differences (Cov.Dif.) Between Bladed Trails (Distb.) and Their Controls (Contr.)

In Rhizocarpon inarense-Umbilicaria probiscidea Tundra (n=2)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ANTEN SP	0 010	1	0	CRE NANA	0 010	1	0	CAR PODO	0 010	1	0
EMP NIGR	0 010	1	0	CAS TETR	0 010	1	0	LEO DECU	0 010	1	0
VAC ULIG	0 010	2	0	POA ARCT	0 010	1	0	OXY DIGY	0 010	1	0
POL VIVI	0 010	1	0	SAL ALAX	0 010	1	0	ALE OCHR	0 085	2	1
ASA CHRY	0 010	1	0	BAE RUFU	0 090	1	0	CET LAEV	0 010	1	0
CET NIVA	0 010	1	0	CET TILE	0.010	1	0	CLA STEL	0 050	2	0
CLA COCC	0 0	1	0	CLA GRAC	0 0	1	0	CLA G GR	0 0	1	0
CLA UNCI	0 0	1	0	CLAD SPP	0 140	1	0	OMP DECU	-0 430	1	1
THA VERM	0 010	1	0	UMB HYPE	0 250	1	0	UMB PROB	-17 405	2	1
CRUSTOSE	-26 500	1	1	SAX LICH	9 000	1	0	CLA SQUA	0 0	1	0
RHI EUPE	12 440	1	0	LEC JOHA	0 0	1	0	LEC STIG	12 500	1	0
BAE CARN	0 0	1	0	HEPATICS	0 0	1	0	MOSS SPP	-1 090	2	2
HYP REVO	0 0	1	0	POH NUTA	0 0	1	0	POL JUNI	0 0	1	0
RHA LANU	0 005	2	2								

-- ----- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
BAC ALPI	0 010	0	1	CLA COCC	-0 010	0	1	CLA DEFO	-0 010	0	1
CLA G GR	0 010	0	1	CLA PLEU	-0 075	0	2	DAC RAMI	-0 010	0	1
OMP KRAS	-0 440	0	1	PAR CENT	-0 010	0	1	PHY CAES	-0 010	0	1
POL SENO	0 0	0	1	UMB HYPE	-3 040	0	1	CRUSTOSE	-8 590	0	1
RHIZO SP	-53 000	0	1	RHI INAR	-9 050	0	1	LEC PANT	0 0	0	1
LECIDEA	0 010	0	1	HEPATICS	0 0	0	1	AND RUPE	0 0	0	2

0.4 Cover Differences (Cov.Dif.) Between Gravel Pits (Distb.) and Their Controls (Contr.)

In *Rhizocarpon inarense*-*Umbilicaria proboscidea* Tundra (n=1)

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR.	SPECIES	COV DIF	DISTB	CONTR
BET GLAN	0 010	1	0	MIN ARCT	0 010	1	0	STL ACAU	0 010	1	0
STELL SP	0 010	1	0	CAR BELL	0 600	1	0	CAR MICH	2 090	1	0
CAR PUDO	0 010	1	0	CAS TETR	0 010	1	0	LED DECU	0 010	1	0
VAC VITI	0 010	1	0	CAL LAPP	0 010	1	0	FES BRAC	0 010	1	0
HIE ALPI	0 010	1	0	POA ARCT	0 010	1	0	TRS SPIC	0 010	1	0
LUZ CONF	0 650	1	0	LUZ NIVA	0 010	1	0	SAL ALAX	0 040	1	0
SAL A XP	0 040	1	0	SAL RETI	0 010	1	0	CET CUCU	0 010	1	0
CET TILE	0 010	1	0	CLA MITI	0 010	1	0	CLA STEL	0 010	1	0
THA SUBU	0 040	1	0	SAX LICH	2 120	1	0	LEC JURA	0 0	1	0
POL COMM	15 540	1	0	POL JUNI	0 010	1	0	POL PILI	0 010	1	0
POL STRI	15 540	1	0								

--------- IN CONTROLS BUT NOT IN DISTURBANCES ----

SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR	SPECIES	COV DIF	DISTB	CONTR
ALE OCHR	-0 010	0	1	BAC ALPI	-0 010	0	1	CLA COCC	0 010	0	1
CLA DEFO	-0 010	0	1	CLA G GR	-0 010	0	1	CLA PLEU	-0 010	0	1
DAC RAMU	-0 010	0	1	OMP DECU	-0 440	0	1	OMP KRAS	0 440	0	1
PAR CENT	-0 010	0	1	PHY CAES	-0 010	0	1	POL SENO	0 0	0	1
CRUSTOSE	-37 500	0	1	RHIZO SP	53 000	0	1	LECIDEA	-0 010	0	1
HEPATICS	0 0	0	1	MOSS SPP	-2 120	0	1	AND RUPE	0 0	0	1
RHA LANU	0 010	0	1								

APPENDIX VI: SHRUB AGES - RAW DATA

Appendix VI
Shrub Ages: Raw Data

Site	Seq	Type	RMP	Veg	Elev	Lat	Long	Date	Diam	Hgt	Species
002	0	0	2219	1	4120	6318	12948	1877	0000	0000	6
003	0	1	2216	1	4120	6318	12947	1959	0450	0000	6
003	0	5	2216	1	4120	6318	12947	1964	0650	0680	6
004	0	1	2202	1	4150	6320	12945	1953	1530	1680	3
004	0	3	2202	1	4150	6320	12945	1951	0780	0320	3
004	0	6	2202	1	4120	6320	12945	1946	1100	1750	6
009	0	3	2165	1	5025	6322	12942	1957	0000	0000	1
009	0	6	2165	1	5030	6322	12942	1950	1720	1800	1
009	0	7	2165	1	5030	6322	12942	1956	1300	1200	1
011	0	1	2165	3	5150	6322	12942	1948	0990	1730	1
014	0	1	2149	3	5160	6324	12940	1960	0850	1300	3
014	0	6	2150	3	5170	6324	12941	1952	0450	0460	3
017	0	3	2123	1	5450	6324	12940	1964	0270	0000	3
017	0	3	2123	1	5450	6324	12940	1962	0360	0000	3
020	0	1	2135	2	5430	6324	12939	1955	0700	0800	1
020	0	5	2135	1	5430	6324	12939	1955	0700	0500	3
020	0	6	2135	1	5430	6324	12939	1953	1100	1000	1
020	0	7	2135	2	5430	6324	12939	1956	0930	1170	1
022	0	6	2126	5	5480	6324	12938	1955	0270	0800	3
023	0	6	2119	8	5610	6324	12938	1952	0480	0900	3
024	0	5	2120	8	5460	6324	12938	1954	0300	0500	3
026	0	1	2120	3	5460	6324	12938	1955	0970	1750	3
028	0	5	2098	1	5165	6326	12934	1952	1180	0500	1
028	1	6	2095	1	5200	6326	12934	1956	1230	0900	1
028	0	1	2095	1	5200	6326	12934	1958	0780	1000	1
030	0	3	2042	1	4250	6326	12926	1949	1350	0800	6
031	0	4	2225	1	4155	6318	12949	1951	1300	1450	3
031	0	5	2225	1	4160	6318	12949	1947	1300	1300	3
031	1	3	2268	1	4350	6317	12956	1956	1250	1150	3
031	1	6	2268	1	4415	6317	12956	1954	1000	0750	3
031	2	3	2226	1	4160	6318	12949	1950	0860	0630	6
031	2	6	2227	1	4120	6318	12949	1948	0870	1200	6
035	0	1	2015	2	4280	6328	12921	1951	2300	2700	1
035	0	6	2015	2	4275	6328	12921	1953	0430	0450	1
037	0	1	2008	1	4430	6328	12919	1955	1050	1000	1
037	0	3	2008	1	4425	6328	12919	1946	1180	1730	1
037	0	3	2008	1	4425	6328	12919	1954	1180	1730	1
037	0	6	2008	1	4420	6328	12919	1956	1530	0620	1
037	0	7	2009	1	4440	6328	12919	1946	1340	0980	1
038	0	1	2006	1	4440	6329	12919	1949	1950	1800	1
042	0	6	1975	1	4610	6331	12916	1949	2900	1060	1
043	0	1	1960	1	4735	6332	12914	1961	0060	0400	2
043	0	1	1960	1	4735	6332	12914	1948	1500	0980	1
043	1	3	1961	1	4750	6332	12914	1957	0900	0320	2
043	1	3	1961	1	4750	6332	12914	1949	1960	1420	1
045	0	6	1948	1	4875	6332	12912	1952	1030	1170	8
047	0	6	1929	1	4880	6334	12912	1944	1520	2650	1
048	0	0	1953	1	4860	6332	12913	1927	0000	0000	2
048	1	6	1912	1	4840	6334	12912	1944	0000	0000	2

continued

Appendix VI continued

Site	Seq	Type	RMP	Veg	Elev	Lat	Long	Date	Diam	Hgt	Species
051	1	6	1881	1	4800	6336	12906	1950	0980	1850	1
051	2	6	1877	1	4780	6336	12906	1947	0930	1330	3
070	0	1	0565	7	3240	6442	12711	1961	1600	1800	1
070	0	2	0565	7	3250	6442	12711	1957	0850	0350	1
070	0	6	0563	7	3240	6442	12711	1950	1500	1300	1
071	0	1	0568	7	3230	6442	12712	1957	0500	0390	1
072	0	1	0619	5	2810	6440	12719	1949	1350	1250	1
072	0	3	0612	5	2680	6440	12718	1951	1120	0820	1
072	0	6	0619	5	2840	6440	12719	1947	1500	1950	1
073	0	2	0624	2	3380	6441	12722	1959	0410	0860	1
074	0	6	0619	2	3100	6440	12721	1950	0600	0550	1
074	1	1	0619	2	3100	6440	12721	1960	0650	1380	1
075	0	1	0635	7	3420	6441	12722	1957	0050	0080	1
076	0	1	0636	5	3410	6441	12722	1957	0340	1040	1
076	0	2	0637	5	3400	6441	12722	1954	0230	0590	3
076	0	6	0636	5	3420	6441	12722	1957	0280	0770	1
077	0	3	0643	5	3140	6440	12723	1949	0950	2050	1
078	0	1	0647	5	3150	6440	12723	1948	0675	1480	1
078	0	6	0647	5	3160	6440	12723	1957	0470	1790	1
078	0	7	0647	5	3150	6440	12723	1956	0540	1480	1
079	0	1	0646	7	3160	6440	12723	1958	0040	0130	3
080	0	1	0662	5	3060	6442	12726	1953	3070	0750	1
081	0	1	0772	2	4445	6436	12742	1961	0520	1100	1
081	0	3	0772	2	4455	6436	12742	1950	0400	0960	1
082	0	1	0789	2	4645	6435	12744	1958	1070	1440	1
083	1	6	0803	6	4830	6434	12744	1951	0070	0550	1
082	0	6	0789	2	4650	6435	12744	1946	0675	0975	1
083	2	6	0803	6	4830	6434	12744	1958	0200	1250	1
083	0	7	0803	6	4835	6434	12744	1950	0400	1600	1
083	0	7	0803	6	4835	6434	12744	1950	0400	1600	1
084	0	1	0805	3	4820	6434	12744	1954	0250	1140	1
084	0	6	0805	3	4830	6434	12744	1945	0270	0980	1
085	0	1	0853	2	5210	6432	12749	1967	0055	0160	1
085	0	6	0853	2	5210	6432	12749	1958	0000	0000	1
085	0	7	0853	2	5210	6432	12749	1962	0035	0210	1
086	0	0	0860	6	4790	6432	12750	1854	0490	1300	1
086	0	3	0860	6	4780	6432	12750	1960	0300	0760	1
086	0	6	0860	6	4780	6432	12750	1954	0370	1520	1
088	0	1	0845	6	5500	6433	12750	1960	0065	0490	1
088	0	3	0847	6	5475	6433	12750	1958	0040	0185	1
088	0	6	0847	6	5465	6433	12750	1956	0075	0380	1
089	0	1	0839	6	5600	6433	12750	1962	0040	0140	1
089	0	3	0841	6	5600	6433	12750	1954	0065	0345	1
090	0	1	0819	6	5115	6434	12748	1960	0125	1015	1
090	0	3	0819	6	5160	6434	12748	1952	0200	0990	1
090	0	6	0819	6	5130	6434	12748	1953	0190	1120	1
091	0	1	0808	6	4840	6434	12745	1950	0155	0770	1
091	0	1	0808	6	4840	6434	12745	1959	0320	1260	1
091	0	1	0808	6	4840	6434	12745	1962	0280	1450	1
091	0	3	0807	6	4850	6434	12745	1950	0230	0630	1
091	0	3	0807	6	4850	6434	12745	1959	0180	0500	1
091	0	3	0807	6	4850	6434	12745	1956	0650	1300	1
092	0	1	0809	8	4740	6434	12745	1960	0300	1700	1
092	0	1	0809	8	4740	6434	12745	1957	0000	0000	1
092	0	1	0809	8	4740	6434	12745	1963	0000	0000	1
092	0	3	0807	8	4680	6434	12745	1957	0290	1340	1
093	0	0	0799	2	4740	6434	12744	1867	0940	1980	1
093	0	1	0799	2	4720	6434	12744	1961	0550	1050	1
093	0	2	0799	2	4700	6434	12744	1949	0580	1190	1
093	0	6	0799	2	4740	6434	12744	1956	0320	0840	1

continued

Appendix VI continued

Site	Seq	Type	RMP	Veg	Elev	Lat	Long	Date	Diam	Hgt	Species
094	0	1	0802	2	4780	6434	12744	1959	0180	0825	1
094	0	1	0802	2	4780	6434	12744	1958	0060	0365	4
094	0	3	0802	2	4780	6434	12744	1952	0410	2250	1
094	0	5	0802	2	4780	6434	12744	1955	0350	1020	1
096	0	1	0834	2	5500	6434	12749	1961	0055	0220	1
096	0	3	0834	2	5490	6434	12749	1959	0110	0480	1
096	0	6	0835	2	5500	6434	12749	1950	0340	0060	1
097	0	1	0828	2	5470	6434	12748	1968	0110	0410	1
098	0	1	0836	7	5520	6433	12750	1953	0040	0130	1
098	0	6	0836	7	5510	6433	12750	1955	0050	0205	1
099	0	1	0875	2	4510	6432	12750	1959	0910	0830	1
099	0	6	0875	2	4515	6432	12750	1954	0670	0480	1
100	0	1	0928	2	3910	6429	12754	1964	0350	1270	1
100	0	6	0927	2	4030	6429	12754	1949	0320	1140	1
100	0	7	0927	2	3975	6429	12754	1951	1700	2680	1
101	0	1	1048	2	4110	6424	12805	1958	0830	2250	1
101	0	3	1047	2	4090	6424	12805	1952	0320	1190	1
101	0	5	1048	2	4120	6424	12805	1952	0200	1050	1
101	0	6	1049	2	4150	6424	12805	1947	1050	1700	1
101	0	7	1049	2	4140	6424	12805	1949	1110	1760	1
101	1	8	1048	2	4120	6424	12805	1970	0210	0255	1
101	3	8	1048	2	4120	6424	12805	1957	0415	1530	1
103	0	1	1103	7	4890	6420	12810	1960	0025	0120	4
104	0	1	1114	4	4660	6420	12813	1959	1050	2600	1
104	0	3	1113	4	4680	6420	12813	1951	0550	1640	3
104	0	6	1115	4	4670	6420	12813	1951	0560	2050	3
106	0	2	1112	7	4610	6420	12812	1957	0530	1330	5
107	0	3	2313	5	4560	6315	13002	1949	1210	0950	3
107	0	5	2313	5	4570	6315	13002	1950	0520	0750	6
107	0	6	2313	5	4590	6315	13002	1956	0810	0970	3
107	0	7	2313	5	4580	6315	13002	1952	1570	1190	3
109	0	1	1107	4	4890	6420	12811	1960	0980	2320	1
109	0	3	1107	4	4810	6420	12811	1950	1080	0950	1
110	0	2	1102	1	4675	6420	12810	1948	2050	0740	7
110	0	6	1100	1	4690	6420	12810	1947	0800	2250	1
111	0	0	1102	4	4930	6420	12810	1813	0990	2950	1
111	0	1	1102	4	4890	6420	12810	1956	1550	2350	1
111	0	3	1102	4	4940	6420	12810	1947	1070	1460	1
111	0	6	1102	4	4920	6420	12810	1953	1370	1050	1
112	0	1	1079	2	4420	6420	12806	1957	0255	1140	1
112	0	3	1079	2	4420	6420	12806	1950	0850	0580	1
112	0	6	1080	2	4420	6420	12806	1968	0700	1330	1
112	0	7	1080	2	4420	6420	12806	1952	0400	1800	1
112	2	8	1080	2	4420	6420	12806	1963	0290	0620	1
113	0	2	1095	2	4550	6420	12809	1954	0780	1020	1
113	0	6	1095	2	4550	6420	12809	1953	0150	0300	1
114	0	1	1069	4	4320	6422	12807	1961	1350	1200	5
115	0	1	1066	4	4360	6422	12807	1960	1470	1400	1
115	0	3	1066	4	4350	6422	12807	1959	0300	0800	1
115	2	8	1066	4	4340	6422	12807	1964	0650	1150	1
117	0	3	2250	1	4310	6317	12953	1946	1140	1310	6
117	0	3	2250	1	4310	6317	12953	1949	1300	1300	3
117	0	6	2250	1	4300	6317	12953	1947	0950	1620	3
118	0	3	2274	1	4430	6317	12957	1949	0930	0680	3
118	0	3	2274	1	4430	6317	12957	1959	0720	0500	6
118	0	6	2274	1	4450	6317	12957	1956	0850	1380	3
118	0	6	2274	1	4450	6317	12957	1956	0910	1120	6

Site - site number (e.g. 001 to 118)
Seq - 0=only disturbance of that type sampled at that site
1=1st, 2=2nd and 3=3rd of two or more disturbances of that type sampled at that site.
Type - Site type
(1) Road
(2) False Start Road
(3) Bladed Trail
(4) Camp Yard
(5) Bulldozer Track
(6) Gravel Pit
(7) Gravel Pit Access Road
(8) Oil Spill
RMP - Road milepost east (e.g. 221.9)
Veg - Physiognomic plant community
(1) Erect Deciduous Shrub Tundra
(2) Decumbent Shrub Tundra
(3) Sedge Meadow Tundra
(4) Lichen Heath Tundra
(5) Fruticose Lichen Tundra
(6) Cushion Plant Tundra
(7) Crustose Lichen Tundra
(8) Forb Meadow Tundra
Elev - Elevation in feet above sea level
Lat - Latitude (e.g. 6318=63 18′ N.L.)
Long - Longitude (e.g. 12948=129 48′)
Date - Minimum year of initiation of shrub growth
Diam - Maximum shrub canopy diameter in centimeters (e.g. 1215=121.5 cm)
Hgt - Maximum shrub canopy height in centimeters (e.g. 670=67.0 cm)
Species - Shrub species sampled
(1) Salix alaxensis
(2) S. reticulata
(3) S. planifolia
(4) S. arctica
(5) S. arbusculoides
(6) Betula glandulosa
(7) Salix lanata
(8) S. glauca

APPENDIX VII: ABOVE-GROUND PHYTOMASS SUPPORTED UPON CANOL DISTURBANCES

Appendix VII
Table A: Average control-corrected (c.c.) and uncorrected (u.) phytomass from control sites and CANOL Project disturbances, N.W.T. (g m^{-2})

Site Type		Herbaceous[a]	Woody	Undifferent-iated	Total[b]	n
Control		668.6	174.8(11.7%)[c]	603.2	1,446.5	34
Road	c.c.	-538.6	-113.0 (20.7%)	-476.3	-1,127.9	30
	u.			103.4	142.5	
False Start Road	c.c.	-793.8	-267.1 (30.8%)	-84.0	-1,144.9	3
		0	35.3	79.3	114.7	
Bladed Trail	c.c.	-574.6	-165.8 (11.0%)	-622.2	-1,362.6	17
	u.	95.8	30.3	149.5	275.0	
Camp Yard	c.c.	-2,050.8	-678.0 (9.3%)	0	-2,728.8	1
	u.	829.0	85.2	0	914.2	
Bulldozer Track	c.c.	-842.8	-170.6 (6.5%)	-501.9	-1,515.3	9
	u.	326.0	6.5	673.8	1,069.7	
Gravel Pit	c.c.	-613.2	-187.0 (24.6%)	-488.6	-1,288.8	25
	u.	6.3	27.2	59.2	92.7	
Gravel Pit Access Road	c.c.	-286.7	-88.4 (38.4%)	-749.7	-1,124.7	8
		33.9	150.2	207.6	391.6	
Oil Spill	c.c.	-1,192.9	-184.9 (0.0%)	-632.4	-2,010.2	10
	u.	0	0	48.2	48.2	

[a] where quantities were large, herbaceous and woody (i.e. stems and leaves) subsamples were taken

[b] total weight is the result of the addition of the 'herbaceous', 'woody' and 'undifferentiated' subsample weights

[c] minimum percentage of total phytomass represented by woody species is recorded in brackets

Appendix VII
Table B: Control-corrected (c.c.) and uncorrected (u) phytomass data from CANOL disturbances, N.W.T. in Erect Deciduous Shrub Tundra

Site Type		Herbaceous	Woody	Undifferent-iated	Total
Control		2849.1	663.5	370.3	3,882.6
Road	c.c.	-3,155.0	-613.2	-381.4	-4,149.6
	u.	0	0	148.6	148.6
False Start Road	c.c.	-1,594.6	-657.4	6.8	-2,245.2
	u.	0	106.0	108.6	214.6
Bladed Trail	c.c.	-2,100.7	-639.2	-487.5	-3,227.4
	u.	196.8	17.6	42.4	256.9
Bulldozer Track	c.c.	-2,910.2	-532.5	392.1	-3,050.7
	u.	153.1	81.2	988.7	1,223.0
Camp Yard	c.c.	-2,050.8	-678.0	0	-2,728.8
	u.	829.0	85.2	0	914.2
Gravel Pit	c.c.	2,136.9	-626.4	-402.0	-3,165.4
	u.	20.0	51.7	42.3	114.0
Gravel Pit Access Road	c.c.	0	-479.4	-786.0	-1,265.4
	u.	0	158.4	273.9	432.3
Oil Spill	c.c.	-4,594.9	-675.9	3.8	-5,267.0
	u.	0	0	3.8	3.8
Total					-25,099.5

Appendix VII
Table C: Control-corrected (c.c.) and uncorrected (u.) phytomass data from CANOL disturbances, N.W.T. in Decumbent Shrub Tundra (g m^{-2})

Site Type		Herbaceous	Woody	Undifferentiated	Total
Control		0	38.1	888.9	927.0
Road	c.c.	0	-2.1	-806.3	-808.4
	u.	0	29.1	126.8	155.9
False Start Road	c.c.	0	0	-350.6	-350.6
	u.	0	0	37.6	37.6
Bladed Trail	c.c	0	-62.8	-831.3	-894.2
	u.	0	5.8	89.7	95.5
Bulldozer Track	c.c.	38.0	-30.4	-886.7	-879.1
	u.	38.0	7.7	319.9	365.6
Gravel Pit	c.c.	0	-3.7	-812.4	-816.1
	u.	0	39.2	21.8	61.0
Gravel Pit Access Road	c.c.	43.6	112.1	-964.1	-808.4
	u.	43.6	150.3	171.1	365.1
Oil Spill	c.c.	0	-68.8	-1,092.6	-1,161.4
	u.	0	0	76.2	76.2
Total					-5,714.2

Appendix VII
Table D: Control-corrected (c.c) and uncorrected (u.) phytomass data from CANOL disturbances, N.W.T. in Sedge Meadow Tundra (g m^{-2})

Site Type		Herbaceous	Woody	Undifferent-iated	Total
Control		186.8	152.9	1,328.8	1,668.5
Road	c.c.	12.3	-249.0	-999.1	-1,235.9
	u.	12.3	5.7	166.1	184.1
Bladed Trail	c.c.	0	0	-1,316.2	-1,316.2
	u.	0	0	1,793.8	1,793.8
Bulldozer Track	c.c.	0	0	-971.2	-971.2
	u.	0	0	2,138.8	2,138.8
Gravel Pit	c.c.	0	-382.2	-291.4	-673.6
	u.	0	0	458.6	458.6
Oil Spill	c.c.	-934.2	0	7.7	-926.5
	u.	0	0	46.1	46.1
Total					-5,123.4

Appendix VII
Table E: Control-corrected (c.c.) and uncorrected (u.) phytomass data from CANOL disturbances, N.W.T. in Lichen Heath Tundra (g m^{-2})

Site Type		Herbaceous	Woody	Undifferentiated	Total
Control		871.0	153.0	884.8	1,908.8
Road	c.c.	-756.8	45.2	-884.8	-1,596.4
	u.	114.2	198.2	0	312.4
Bladed Trail	c.c.	-555.0	-60.4	-884.8	-1,500.2
	u.	316.0	92.6	0	408.6
Gravel Pit	c.c.	-871.0	-153.0	-854.C	-1,878.0
	u.	0	0	30.8	30.8
Oil Spill	c.c.	-871.0	-153.0	-883.8	-1,907.8
	u.	0	0	1.0	1.0
Total					-6,882.4

Appendix VII

Table F: Control-corrected (c.c.) and uncorrected (u.) phytomass data from CANOL disturbances, N.W.T. in Fruticose Licher Tundra (g m^{-2})

Site Type		Herbaceous	Woody	Undifferent-iated	Total
Control		957.9	175.9	515.4	1,649.1
Road	c.c.	-939.0	-71.1	133.8	-876.4
	u.	54.8	107.7	133.8	296.3
False Start Road	c.c.	-786.8	-143.8	91.8	-838.8
	u.	0	0	91.8	91.8
Bladed Trail	c.c.	-405.3	56.3	-1,004.0	-1,353.0
	u.	259.5	160.5	26.9	446.9
Bulldozer Track	c.c.	515.5	76.8	-1,030.9	-438.6
	u.	1,180.3	181.0	0	1,361.3
Gravel Pit	c.c.	-943.4	-149.2	-493.7	-1,586.2
	u.	14.4	26.7	21.8	62.9
Gravel Pit Access Road	c.c.	-1,212.2	-42.2	-769.3	-2,023.7
	u.	70.2	216.8	261.6	548.6
Total					-7,116.7

Appendix VII

Table G: Control-corrected (c.c) and uncorrected (u.) phytomass data from CANCL disturbances, N.W.T. in Cushion Plant Tundra (g m^{-2})

Site Type		Herbaceous	Woody	Undifferent-iated	Total
Control		0	0	79.9	79.9
Road	c.c.	C	0	-57.2	-57.2
	u.	0	0	25.1	25.1
Bladed Trail	c.c.	0	0	-56.5	-56.5
	u.	0	0	24.4	24.4
Gravel Pit	c.c.	0	0	-79.7	-79.7
	u.	0	0	1.2	1.2
Gravel Pit Access Road	c.c.	0	0	5.6	5.6
	u.	0	0	76.0	76.0
Total					-187.8

Appendix VII

Table H: Control-corrected (c.c) and uncorrected (u.) phytomass data from CANOL disturbances, N.W.T. in Crustose Lichen Tundra (g m^{-2})

Site Type		Herbaceous	Woody	Undifferent-iated	Total
Control	0	0	0	204.4	74.1
Road	c.c.	0	0	-46.0	-46.0
	u.	0	0	28.1	28.1
Bladed Trail	c.c.	0	0	-91.8	-91.8
	u.	0	0	1.4	1.4
Gravel Pit	c.c.	0	0	-27.4	-27.4
	u.	0	0	27.6	27.6
Total					-165.2

APPENDIX VIII: WILDLIFE - RAW DATA

Site	Seq	Type	RMP	Veg	Elev	Lat	Long	%Cover			Carib		Moose		Sheep		Horse			Grnd.Squ				Microtine				Pt	Fx	Wf		
								O	M	P	Trl	Drop	Drop	Trl	Trl	Drop	Trl	Drop	GT	Trl	Drop	Dig	Bur	Trl	Drop	Bur	Pk	Drop	Drop	Drop	Bear	Other
002	0	0	2219	1	4120	6318	12948	0752	0000	9248										07		01										
002	0	1	2219	1	4120	6318	12948	0259	6300	3441																						
002	0	5	2219	1	4120	6318	12948	0320	0015	9665	01			01			02	04		05			01		02			02	02	01		01
002	0	6	2219	1	4120	6318	12948	0015	9782	0203																						
002	0	7	2219	1	4120	6318	12948	0015	9782	0203																						
003	0	0	2216	1	4120	6318	12947	0137	0000	9863																						
003	0	1	2216	1	4120	6318	12947	0500	2000	7500	01						05	03												02		
003	0	3	2216	1	4120	6318	12947	0547	4350	5103	05		01					02				01	02					01				
003	1	8	2216	1	4120	6318	12947	3600	6200	0043	01		01																			
009	0	0	2165	1	5030	6322	12942	0280	0210	9510	01													06		15		01				
009	0	1	2165	1	5025	6322	12942	0752	3800	5448							05												01			
009	0	3	2165	1	5025	6322	12942	0203	4201	4405	08		02															02		01		
009	0	5	2165	1	5030	6322	12942	0091	2700	7209	05		01																			
009	0	6	2165	1	5030	6322	12942	0045	8550	1405	04							01														
009	0	7	2165	1	5030	6322	12942	0065	3950	5985	04		01					01														
011	0	0	2165	3	5160	6322	12942	0901	0000	9099	02													21		17						
011	0	1	2165	3	5150	6322	12942	0901	0000	9099							02	02		01			01									
014	0	0	2149	3	5160	6324	12940	0055	0271	9675	03		03											15	00	26						
014	0	1	2149	3	5160	6324	12940	0075	8100	1825								03				05								01		01
014	0	6	2150	3	5170	6324	12941	0213	0958	8829	03		01										01		02							
016	0	0	2135	3	5325	6324	12939	0001	0000	9999	04	02									19		05	09	17							02
016	0	3	2135	3	5325	6324	12939	0075	0000	9925	13	01												12	06						01	
016	0	5	2135	3	5325	6324	12939	3250	0000	6750	05	12													99	37						
020	0	0	2135	2	5430	6324	12939	0352	0005	9643	02												01	01								
020	0	1	2135	2	5430	6324	12939	0454	3200	6346	06						02					01	01									
020	0	5	2135	2	5430	6324	12939	0752	0015	9233	02	02									02		01	03		03						
020	0	6	2135	2	5430	6324	12939	0000	9999	0001	04							01														
020	0	7	2135	2	5430	6324	12939	0000	1450	8550	17							01					01									
031	0	0	2227	1	4160	6318	12949	0055	0000	9945									03													
031	0	4	2225	1	4155	6318	12949	0912	0111	8977								20										02				02
031	0	5	2225	1	4160	6318	12949	0752	0010	9238		02					01	07	01				01					01				
031	2	3	2226	1	4160	6318	12949	0055	2750	7195		01						02							19							
031	2	6	2227	1	4120	6318	12949	0542	4800	4658		01						05										02				
031	2	8	2225	1	4150	6318	12949	3450	5750	0800		01		01			02								08			05				
035	0	0	2015	2	4285	6328	12921	2201	1152	6647	03		01							02												
035	0	1	2015	2	4280	6328	12921	2751	5250	1999	01							04				13						03		01		
035	0	3	2015	2	4280	6328	12921	0045	8600	1355			03				01			01	01	02										
035	0	6	2015	2	4275	6328	12921	0015	9550	0435	08			01			07		01									01				
037	0	0	2008	1	4425	6328	12919	0454	0000	9546	01		01	08				02	01							04		08				
037	0	1	2008	1	4430	6328	12919	0245	9300	0455				02				04	01			07									02	
037	0	3	2008	1	4425	6328	12919	0167	6700	3133			03	02			07	01								01						
037	0	6	2008	1	4420	6328	12919	1015	0000	9885			01	01			08	0														
037	0	7	2009	1	4440	6328	12919	0454	0465	9081	01		01	05			03					08						03				
072	0	0	0619	5	2840	6440	12719	0010	0020	9970																						
072	0	1	0619	5	2810	6440	12719	0603	7650	0747		02																06				

continued

Appendix VIII continued

								%Cover			Carib		Moose		Sheep		Horse			Grnd.Squ				Microtine				Pt	Fx	Wf		
Site	Seq	Type	RMP	Veg	Elev	Lat	Long	O	M	P	Trl	Drop	Drop	Trl	Trl	Drop	Trl	Drop	GT	Trl	Drop	Dig	Bur	Trl	Drop	Bur	Pk	Drop	Drop	Drop	Bear	Other
072	0	3	0612	5	2680	6440	12718	0101	4440	5459																		05				
072	0	5	0611	5	2680	6440	12718	0000	0000	9999																		05				
072	0	6	0619	5	2840	6440	12719	0147	3200	6653																						
074	0	0	0619	2	3100	6440	12721	0362	1591	8047																						
074	0	6	0619	2	3100	6440	12721	0035	9300	0665																						
074	1	1	0619	2	3100	6440	12721	0398	5250	4352	01																					
074	2	1	0619	2	3100	6440	12721	2050	0015	7935				01																		
075	0	0	0635	7	3420	6441	12722	0035	0055	9910																	01					
075	0	1	0635	7	3420	6441	12722	0020	8550	1430																	03					
076	0	0	0636	5	3420	6441	12722	0167	0065	9768																						
076	0	1	0636	5	3410	6441	12722	0752	3850	5398	01					13											01					
076	0	2	0637	5	3400	6441	12722	0111	7650	2239						03																
076	0	6	0636	5	3420	6441	12722	0040	8100	1860	01																					
078	0	0	0647	5	3170	6440	12723	0101	0076	9823																						
078	0	1	0647	5	3150	6440	12723	0598	4800	4602	01					01												03				
078	0	6	0647	5	3160	6440	12723	0065	9550	0385						01																
078	0	7	0647	5	3150	6440	12723	0081	6250	3669						06																
082	0	0	0789	2	4685	6435	12744	0075	1405	8520	01																					
082	0	1	0789	2	4645	6435	12744	0030	8350	1620																		01		01		
082	0	6	0789	2	4650	6435	12744	0030	9300	0670																						
083	0	0	0803	6	4840	6434	12744	0496	7900	1604																						
083	0	6	0803	6	4830	6434	12744	0010	9800	0190																						
083	0	7	0803	6	4835	6434	12744	0050	8800	1150	03																					
084	0	0	0805	3	4820	6434	12744	0147	7200	2653																						
084	0	1	0805	3	4820	6434	12744	0025	8600	1375						01		01										02				
084	0	6	0805	3	4830	6434	12744	0147	7200	2653																						
087	0	0	0843	6	5610	6433	12750	0055	6200	3745						03							01									
087	0	1	0843	6	5610	6433	12750	0010	9800	0190																						
088	0	0	0843	6	5610	6433	12750	0055	6200	3745						03							01									
088	0	1	0845	6	5500	6433	12750	0000	9990	0010																						
088	0	3	0847	6	5475	6433	12750	0000	9550	0450																						
088	0	6	0847	6	5465	6433	12750	0000	9999	0000																						
089	0	0	0843	6	5610	6433	12750	0055	6200	3745						03							01									
089	0	1	0839	6	5600	6433	12750	0010	9978	0012																						
089	0	3	0841	6	5600	6433	12750	0025	7675	2325																						
089	0	6	0839	6	5600	6433	12750	0000	9995	0005	01					12												01				
091	0	0	0803	6	4840	6434	12744	0496	7900	1604																						
091	0	1	0808	6	4840	6434	12745	0035	9300	0665						03												07				
091	0	3	0807	6	4850	6434	12745	0035	8100	1865						01																
093	0	0	0799	2	4740	6434	12744	1050	0121	8829	01												02									
093	0	1	0799	2	4720	6434	12744	0000	8800	1200								02														
093	0	2	0799	2	4700	6434	12744	0316	6100	3540	01																					
093	0	6	0799	2	4740	6434	12744	0065	7650	2285	05					01																
094	0	0	0802	2	4780	6434	12744	0603	0000	9397	10							01					01									
094	0	1	0802	2	4780	6434	12744	0075	7850	2075	06																					
094	0	3	0802	2	4780	6434	12744	0045	8800	1155	30				01																	
094	0	5	0802	2	4780	6434	12744	0454	0896	8650	20				02			01					01									

continued

Appendix VIII continued

								%Cover			Carib		Moose		Sheep		Horse			Grnd.Squ				Microtine				Pt	Fx	Wf		
Site	Seq	Type	RMP	Veg	Elev	Lat	Long	O	M	P	Tr1	Drop	Drop	Tr1	Tr1	Drop	Tr1	Drop	GT	Tr1	Drop	Dig	Bur	Tr1	Drop	Bur	Pk	Drop	Drop	Drop	Bear	Other
096	0	0	0834	2	5490	6434	12749	0901	0127	8972						09												03				
096	0	1	0834	2	5500	6434	12749	0025	7650	3325		05																05				
096	0	3	0834	2	5490	6434	12749	0025	6200	3775						01												01				
096	0	6	0835	2	5500	6434	12749	0015	9550	0435		01																				
098	0	0	0836	7	5520	6433	12750	0213	0408	9379																						
098	0	1	0836	7	5520	6433	12750	0025	9800	0175		02			03	01																
098	0	6	0836	7	5510	6433	12750	0000	9995	0005																						
101	0	0	1048	2	4130	6424	12805	0001	0000	9999						02							01									01
101	0	1	1048	2	4110	6424	12805	0803	6700	2407								04	01			13						02			03	
101	0	3	1047	2	4090	6424	12805	0296	4800	4904	03												02					01				
101	0	5	1048	2	4120	6424	12805	0706	4145	5149												02										
101	0	6	1049	2	4150	6424	12805	0213	6250	3537												02						03				
101	0	7	1049	2	4140	6424	12805	0752	3400	5848	01					01						99						10				
101	1	8	1048	2	4120	6424	12805	1050	1055	7895																						
103	0	0	1103	7	4910	6420	12810	0061	1101	8839																	01					
103	0	1	1103	7	4890	6420	12810	0075	5750	4175	04							01														
103	0	6	1103	7	4900	6420	12810	0081	5150	4769																						
104	0	0	1115	4	4680	6420	12813	0454	0060	9486																						
104	0	1	1114	4	4660	6420	12813	0952	5450	2598		02		01		07		05										02				
104	0	3	1113	4	4680	6420	12813	0757	2345	6898	01					01															01	
104	0	6	1115	4	4670	6420	12813	0025	8100	1875																						
104	1	8	1115	4	4640	6420	12813	4951	3302	1747																						
105	0	0	1115	3	4630	6420	12813	1152	0742	8106	01					01																
105	1	8	1115	3	4630	6420	12813	6700	0010	3299	01		01																			
105	2	8	1115	3	4630	6420	12813	7200	1450	1350	01					02																02
107	0	0	2313	5	4570	6315	13002	0362	0005	9633	02									06				03	03	02						
107	0	3	2313	5	4560	6315	13002	0085	8150	1765	01						01						01									
107	0	5	2313	5	4570	6315	13002	0901	0000	9099	02		01																			
107	0	6	2313	5	4590	6315	13002	0101	9550	0349	01							01				03										
107	0	7	2313	5	4580	6315	13002	0259	0408	9333							01															
110	0	0	1102	1	4690	6420	12810	0752	0025	9223										05			01									
110	0	2	1102	1	4675	6420	12810	0352	4951	4697	03			01	01	03		05	01			22										
110	0	6	1100	1	4690	6420	12810	0203	7650	2147	07	02										10										
112	0	0	1079	2	4420	6420	12806	2050	0050	7900		01									01	01	02									
112	0	1	1079	2	4420	6420	12806	0000	9100	0900																						
112	0	3	1079	2	4420	6420	12806	0306	3750	5944	22				02		01					01										
112	0	6	1080	2	4420	6420	12806	0035	8000	1965	15				04																	
112	0	7	1080	2	4420	6420	12806	0157	6200	3643	03				01																	
112	0	9	1080	2	4420	6420	12806	1851	0706	7443							99	29			02		02					02				
112	2	8	1080	2	4420	6420	12806	0055	9930	0015	09				04		35															

Site - site number (e.g. 001 to 118)
Seq - 0=only disturbance of that type sampled at that site
1=1st, 2=2nd and 3=3rd of two or more disturbances of that type sampled at that site.
Type - Site type
(1) Road
(2) False Start Road
(3) Bladed Trail
(4) Camp Yard
(5) Bulldozer Track
(6) Gravel Pit
(7) Gravel Pit Access Road
(8) Oil Spill
RMP - Road milepost east (e.g. 221.9)
Veg - Physiognomic plant community
(1) Erect Deciduous Shrub Tundra
(2) Decumbent Shrub Tundra
(3) Sedge Meadow Tundra
(4) Lichen Heath Tundra
(5) Fruticose Lichen Tundra
(6) Cushion Plant Tundra
(7) Crustose Lichen Tundra
(8) Forb Meadow Tundra
Elev - Elevation in feet above sea level
Lat - Latitude (e.g. 6318=63°18′ N.L.)
Long - Longitude (e.g. 12948=129°48′)
%Cover - O=Organic (e.g. 0259=2.59%)
M=Mineral (e.g. 6300=63.00%)
P=Plant (e.g. 3441=34.41%)

Carib - Caribou
Trl - Trails
Drop - Pellet groupings or scats
Dig - Diggings
Bur - Burrows
Res - Resident
G.T. - Game Trail
Grnd.Squ - Arctic ground squirrel
Pk - Pika
Pta - Ptarmigan
Fx - Fox
Wf - Wolf
Bear - Grizzly bear
Other - miscellaneous counts (e.g. raptor pellets, bone. etc.)